

N 65 16759

FACILITY FORM 602

(ACCESSION NUMBER)

91

(THRU)

(PAGES)

CTR-54252

(NASA CR OR TMX OR AD NUMBER)

(CODE)

08

(CATEGORY)

GPO PRICE \$ _____

OTS PRICE(S) \$ _____

Hard copy (HC) \$ 3.00

Microfiche (MF) \$ 0.75

MANUAL

COMPUTER PROGRAM FOR DESIGNING
SHELL-AND-TUBE LIQUID METAL CONDENSERS
Report PWA-2370

prepared for
National Aeronautics and Space Administration
Contract NAS3-2335

August 1964
(Revised January 1965)



Written by H. L. Ornstein H. L. Ornstein, Sen. Anal. Engr.

S. S. Wyde S. S. Wyde, Asst. Proj. Engr.

Approved by H. R. Kunz H. R. Kunz, Program Manager

W. J. Lueckel W. J. Lueckel, Chief,
Space Power Systems

Pratt & Whitney Aircraft

DIVISION OF UNITED AIRCRAFT CORPORATION



E A S T H A R T F O R D • C O N N E C T I C U T

COPY NO. 11

FOREWORD

This report is a manual of computer programming for the design of shell-and-tube liquid metal condensers. It was prepared by the Pratt & Whitney Aircraft Division of United Aircraft Corporation for the National Aeronautics and Space Administration, Lewis Research Center, under Contract NAS3-2335, Experimental Investigation of Heat Rejection Problems in Nuclear Space Powerplants.

TABLE OF CONTENTS

	<u>Page</u>
Foreword	ii
Table of Contents	iii
I. Introduction	1
II. Card Input Instructions	2
III. Printout Format	8
Appendix 1 - Tables	10
Appendix 2 - Methods of Calculating Condensing Heat Transfer Coefficient	18
Appendix 3 - Definitions of Blockage, Tube Entrance Loss Coefficient Modifier, Number of Tube Rows, Tube Taper, Shell Taper, Shell Entrance and Exit Pressure Loss Coefficients	22
Appendix 4 - Error Printouts	27
Appendix 5 - List of Computer Statements	31
Appendix 6 - Computer Flow Diagrams	86

I. INTRODUCTION

16759 This manual presents operational information for the computer program used to design liquid metal condensers described in Report PWA-2320, Analytical Study of Liquid Metal Condenser, Volume I, "Design Study". That report discusses the overall philosophy and logic of the computer program. The present manual covers the following items in detail:

- 1) Input format and instructions,
- 2) Printout format,
- 3) Computer flow diagram (Appendix 6), and
- 4) List of computer statements (Appendix 5).

For a particular set of flows, thermodynamic end states, and cross-sectional geometries, the program generates:

- 1) Tube length,
- 2) Core weight and volume,
- 3) Pressure losses of both fluids, and
- 4) Temperature profiles of both fluids along the length of the condenser.

The program is limited to:

- 1) Condensing fluid flow inside of tubes and coolant flow along the outside of tubes,
- 2) Single-pass counterflow cooling arrangement,
- 3) Diameters of tubes and shell either varying or constant with length, but not varying shell diameter with constant tube diameter, and
- 4) Equilateral triangular tube pattern.

This program is coded in Fortran II.

Author

II. CARD INPUT INSTRUCTIONS

A. Instructions for First Case

Enter the cards in the following order:

1. Title Card

Enter title in Columns 2 through 72.

2. Control Card

The outline below shows the field locations of the various items used to control the program. The symbols are defined in Tables 1 and 2.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
LIMIT LIMIT ITTRATN ITERAT ISCHRJ IKON ICHANG KURVE 15 KURVE 14 KURVE 13 KURVE 12 KURVE 11 KURVE 10 KURVE 9 KURVE 8 KURVE 7 KURVE 6 KURVE 5 KURVE 4 KURVE 3 KURVE 2 KURVE 1 N M

All items must be entered as fixed point right adjusted numbers.

<u>Symbol</u>	<u>Instruction</u>
N	- Enter the desired number of increments in the condensing section (must be an integer greater than zero)
M	- Enter the desired number of increments in the subcooling section (must be an integer greater than zero)
KURVE 1-15	- Enter one (1) in each location - This instructs the machine that it will receive input on all properties in tabular form (see curve cards)
ICHANG	- Enter zero (0). This instructs the machine that a master case is being loaded into the machine.

<u>Symbol</u>	<u>Instruction</u>
IKON	<p>- Enter one (1) if it is desired to use Option I to calculate condensing heat transfer coefficients.</p> <p>Enter two (2) if it is desired to use Option II to calculate condensing heat transfer coefficients.</p> <p>Enter three (3) if it is desired to use Option III to calculate condensing heat transfer coefficients.</p> <p>These three options are described in Appendix 2.</p>
ISCHRJ	<p>- Enter one (1) if it is desired to take Schrage effect into account. See Appendix 2.</p> <p>Enter zero (0) if Schrage effect is to be neglected.</p>
ITERAT	<p>- Applies only to tapered heat exchanger equations. Ignore for constant-diameter exchanger.</p> <p>Enter one (1) if program is to calculate incremental lengths in the condensing section using an iterative procedure. This iterative procedure is described in Report PWA-2320, Volume 1, Section V. This procedure accounts for tube and shell tapers in each increment.</p> <p>Enter zero (0) if the incremental lengths in the condensing section are to be calculated using a noniterative procedure. This procedure assumes that each increment has constant shell and tube diameters. The values of diameter for each increment are determined as a function of length from the tube entrance.</p>
ITRATN	<p>- Applies only to tapered heat exchanger equations. Ignore for constant-diameter heat exchanger.</p> <p>Enter one (1) if the incremental lengths in the subcooling section are to be calculated using the iterative procedure.</p>

Enter zero (0) if incremental lengths in the subcooling section are to be calculated using the noniterative procedure.

LIMIT - Applies only to tapered heat exchanger equations. Ignore for constant-diameter heat exchanger.

Enter the maximum number of iterations desired for any one condensing section increment if the iteration procedure is to be used. Ignore if noniterative procedure is used.

LIMITN - Applies only to tapered heat exchanger equations. Ignore for constant-diameter heat exchanger.

Enter the maximum number of iterations desired for any one subcooling section increment if the iteration procedure is to be used. Ignore if noniterative procedure is used.

3. Data Cards

Six data cards are entered with the format shown below (nomenclature is listed in Table 1). All data in input is in floating point mode in the field widths indicated.

1-14	15-28	29-42	43-56	57-70
WTDOT	TINT	TOUTT	TOOTS	XINT
XOUTT	ALPHA1	ALPHA2	WSDOT	TTS
TS	DT	TW	B	ZNT
PHUJ	PINT	ZNRO	R TW	RSW
RTS	AFUDGE	SIGMA	ZMOL	GAMT
GAMS	DIMIN			

4. Curve Cards (34 Cards)

The various fluid properties used in the program are entered as functions of either temperature or pressure. Table 2 lists the properties and their independent variable. The input instructions are as follows:

Curves one (1) to twelve (12), and curve fifteen (15) each require two input cards. The first card, an abscissa card, contains five values of independent variable (temperature), arranged in increasing order of magnitude. The second, an ordinate card, contains five values of the dependent variable, arranged in an order corresponding to the abscissa values. See sample below. All curve values for KURVE 1 through 12 and 15 are entered in floating point mode, in the field widths shown below.

1-14	15-28	29-42	43-56	57-70
TEMP1	TEMP2	TEMP3	TEMP4	TEMP5
f(TEMP1)	f(TEMP2)	f(TEMP3)	f(TEMP4)	f(TEMP5)

Curves thirteen (13) and fourteen (14) each require four input cards. The first two cards are abscissa cards each containing five values of the independent variable (i.e., temperature or pressure), arranged in increasing order of magnitude. The last two cards are ordinate cards, each containing five values of the dependent variables arranged in an order corresponding to the abscissa values. See sample below. All curve values are entered in floating point mode and in the field widths indicated.

For KURVE 13

1-14	15-28	29-42	43-56	57-70
TEMP 1	TEMP 2	TEMP 3	TEMP 4	TEMP 5
TEMP 6	TEMP 7	TEMP 8	TEMP 9	TEMP 10
vapor density 1	vapor density 2	vapor density 3	vapor density 4	vapor density 5
vapor density 6	vapor density 7	vapor density 8	vapor density 9	vapor density 10

For KURVE 14

1-14	15-28	29-42	43-56	57-70
pressure 1	pressure 2	pressure 3	pressure 4	pressure 5
pressure 6	pressure 7	pressure 8	pressure 9	pressure 10
sat temp 1	sat temp 2	sat temp 3	sat temp 4	sat temp 5
sat temp 6	sat temp 7	sat temp 8	sat temp 9	sat temp 10

Note: The range of the independent variables should be sufficiently wide since the curve-reading subroutine will not extrapolate curves. If the computer calculates values of independent variables which are beyond the input range of the curves, an error printout will result and all calculations on that case will cease.

B. Instructions for Each Succeeding Case

This procedure should be used if it is desired to run a number of cases in one loading when only a few input items are changed.

Load cards immediately behind the preceding case in the following order:

1. Title Card

2. Control Card

N - Enter number of increments in the condensing section (must be an integer greater than zero)

M - Enter number of increments in the subcooling section (must be an integer greater than zero)

KURVE 1-15 - Enter zero (0) in appropriate column if curve from preceding case is to be used unchanged

Enter one (1) in appropriate column if it is desired to change curve from preceding case

ICHANG - Enter one (1). This instructs the machine that one or more input items from the previous case will be changed

IKON, ISCHRJ, ITERAT, ITRATN, LIMIT, LIMITN - Enter value for desired options as described for first case

3. Input Change Cards

For each input item on data cards to be changed from preceding case, enter a card with the input as follows:

a. Column (1-2) - Identification number of variable to be changed (see Table 1). Identification number must be entered as a fixed point right displaced number

b. Column (3-16) - New value of input item in floating point mode.

4. Blank Card

5. Changed Curve Cards

Each curve to be changed requires abscissa and ordinate cards as previously described. All such sets of curve cards are to be arranged in ascending order, (i.e., if it is desired to change KURVES 1 and 3 then the two cards for KURVE 1 must be placed first, followed by the two cards for KURVE 3).

C. Instructions to End Deck

After the last case input, place an additional blank card, then a card with a minus sign (-) in column one and a one (1) in column two.

III. PRINTOUT FORMAT

A sample of the printout format of the program is shown in Table 3. The information contained in this format is arranged in three blocks which appear in the following order:

Block 1

A tabulation of the input data. All property curves are listed for the first case. On all other cases only the curves which were changed from the preceding case are printed. The symbols, definitions and units for the input data appear in Table 1.

Block 2

Tabulations of the local conditions at each increment along the length of the condensing and subcooling sections.

Block 3

A tabulation of the final calculated values of the important parameters. The symbols, definitions and units of these final calculated values are listed in Table 4.

A. Description of Block 2

The local conditions at each increment along the length of the condensing and subcooling regions are printed out in four different sections. Each of these sections is described below and the corresponding printout format for each section is given in Table 5.

1. Condensing Section

The first printed line below the column headings describes the conditions at the inlet to the first increment of the condensing region. It should be noted that the tube fluid inlet pressure of this increment is the static pressure of the condensing fluid after the entrance pressure loss has been calculated. The tube fluid inlet temperature is the saturation temperature corresponding to the inlet static pressure. The next N printed lines (N = number of increments in the condensing region) describe the local conditions at the exit of each increment along the length of the condensing region.

2. Condensing Section (continued)

This section contains additional information about the inlet to the first increment of the condensing region and the exit of each of the N increments. The tube fluid qualities are repeated for ease of increment identification.

3. Subcooling Section

The first printed line below the column headings describes the conditions at the inlet to the first increment of the subcooling region.

The next M printed lines (M = number of increments in subcooling region) describe the local conditions at the exit of each increment along the length of the subcooling region.

4. Subcooling Section (continued)

This section contains additional information about the inlet to the first increment of the subcooling region and the exit of each of the M increments. The tube fluid temperatures are repeated for ease of increment identification.

In the event that an error was made in the input to the program, such that the result violates certain program rules, then an error printout will occur. The details of error printouts are described in Appendix 4.

APPENDIX 1

Tables

TABLE 1
Input Data

<u>Symbol</u>	<u>Ident- Number</u>	<u>Definition</u>
WTDOT	1	total weight flow through tubes, lb/hr
TINT	2	inlet temperature of tube fluid, °F
TOUTT	3	outlet temperature of tube fluid, °F
TOUTS	4	outlet temperature of shell fluid, °F
XINT	5	inlet quality of tube fluid
XOUTT	6	outlet quality of tube fluid*
ALPHA 1	7	sum of entrance pressure loss coefficients for flow through shell (see Appendix 3)
ALPHA 2	8	sum of exit pressure loss coefficients for flow through shell (see Appendix 3)
WSDOT	9	total weight flow of fluid through shell, lb/hr
TTS	10	thickness of tubesheet, inches
TS	11	thickness of shell wall, inches
DT	12	inside diameter of tube, inches
TW	13	tube wall thickness, inches
B	14	shell blockage (see Appendix 3 for details)
ZNT	15	total number of tubes
PHUJ	16	tube entrance loss coefficient modifier (see Appendix 3 for details)
PINT	17	inlet pressure of tube fluid, psia
ZNRO	18	number of tube rows (see Appendix 3 for details)
RTW	19	density of tube wall, lb/ft ³
RSW	20	density of shell wall, lb/ft ³
RTS	21	density of tube sheet, lb/ft ³
AFUDGE	22	constant defined in Appendix 2
SIGMA	23	Schrage's condensation coefficient (see Appendix 2)
ZMOL	24	molecular weight of tube fluid
GAMT	25	tube taper (see Appendix 3 for details)
GAMS	26	shell taper (see Appendix 3 for details)
DIMIN	27	minimum allowable tube inside diameter, inches

* If XOUTT > 0, then calculations of expansion pressure losses at exit are based upon liquid portion of flow only

TABLE 2

Definition of Independent and Dependent Variables

The curve cards are entered in the order listed.

	<u>Number of Cards</u>	<u>Independent Variable</u>	<u>Dependent Variable</u>
Kurve 1	2	temperature of vapor in tube, °F	specific heat C_p of vapor in tube, Btu/lb °F
Kurve 2	2	temperature of vapor in tube, °F	dynamic viscosity of vapor in tube, lb/hr ft
Kurve 3	2	temperature in vapor in tube °F	thermal conductivity of vapor in tube, Btu/hr ft °F
Kurve 4	2	temperature of liquid in tube, °F	specific heat of liquid in tube, Btu/lb °F
Kurve 5	2	temperature of liquid in tube, °F	density of liquid in tube, lb/ft ³
Kurve 6	2	temperature of liquid in tube, °F	dynamic viscosity of liquid in tube, lb/hr ft
Kurve 7	2	temperature of liquid in tube, °F	thermal conductivity of liquid in tube, Btu/hr ft °F
Kurve 8	2	temperature of liquid in shell, °F	specific heat of liquid in shell, Btu/lb °F
Kurve 9	2	temperature of liquid in shell, °F	density of liquid in shell, lb/ft ³
Kurve 10	2	temperature of liquid in shell, °F	dynamic viscosity of liquid in shell, lb/hr ft
Kurve 11	2	temperature of liquid in shell, °F	thermal conductivity of liquid in shell, Btu/hr ft °F
Kurve 12	2	saturation temperature of fluid in tube, °F	latent heat of vaporization of fluid in tube, Btu/lb
Kurve 13	4	temperature of vapor in tube, °F	density of vapor in tube, lb/ft ³
Kurve 14	4	saturation pressure of fluid in tube, psia	saturation temperature of fluid in tube, °F
Kurve 15	2	temperature of tube wall, °F	thermal conductivity of tube wall material, Btu/hr ft °F

CONDENSING SECTION (CONT'D)

QUALITY	H TUBE	H SHELL	OVERALL HEAT TRANS. COEFF U	RE TUBE VAPOR	RE SHELL	STATIC PRESSURE	INCREMENTAL DP FRICTION
0.83000E 00	0.83485E 04	0.55529E 04	0.27171E 04	0.18278E 05	0.61062E 04	0.38407E 01	0.59003E-02
0.80925E 00	0.86846E 04	0.55797E 04	0.27621E 04	0.18364E 05	0.62612E 04	0.38307E 01	0.59003E-02
0.78850E 00	0.90054E 04	0.56044E 04	0.28037E 04	0.18403E 05	0.64077E 04	0.38227E 01	0.59090E-02
0.76775E 00	0.93013E 04	0.56273E 04	0.28412E 04	0.18396E 05	0.65470E 04	0.38169E 01	0.59077E-02
0.74700E 00	0.95733E 04	0.56487E 04	0.28752E 04	0.18348E 05	0.66801E 04	0.38132E 01	0.58953E-02
0.72625E 00	0.98225E 04	0.56688E 04	0.29062E 04	0.18263E 05	0.68078E 04	0.38117E 01	0.58710E-02
0.70550E 00	0.10049E 05	0.56878E 04	0.29343E 04	0.18142E 05	0.69306E 04	0.38124E 01	0.58345E-02
0.68475E 00	0.10254E 05	0.57058E 04	0.29599E 04	0.17988E 05	0.70491E 04	0.38154E 01	0.57915E-02
0.66400E 00	0.10438E 05	0.57230E 04	0.29831E 04	0.17803E 05	0.71638E 04	0.38201E 01	0.60772E-02
0.64325E 00	0.10601E 05	0.57393E 04	0.30043E 04	0.17588E 05	0.72751E 04	0.38270E 01	0.60443E-02
0.62250E 00	0.10743E 05	0.57550E 04	0.30233E 04	0.17346E 05	0.73833E 04	0.38360E 01	0.60005E-02
0.60175E 00	0.10865E 05	0.57701E 04	0.30405E 04	0.17076E 05	0.74887E 04	0.38471E 01	0.59459E-02
0.58100E 00	0.10967E 05	0.57845E 04	0.30558E 04	0.16781E 05	0.75916E 04	0.38603E 01	0.58810E-02
0.56025E 00	0.11048E 05	0.57985E 04	0.30694E 04	0.16461E 05	0.76921E 04	0.38755E 01	0.58062E-02
0.53950E 00	0.11109E 05	0.58120E 04	0.30812E 04	0.16117E 05	0.77906E 04	0.38926E 01	0.57218E-02
0.51875E 00	0.11150E 05	0.58251E 04	0.30914E 04	0.15750E 05	0.78873E 04	0.39116E 01	0.56285E-02
0.49800E 00	0.11171E 05	0.58379E 04	0.30999E 04	0.15360E 05	0.79822E 04	0.39324E 01	0.55266E-02
0.47725E 00	0.11172E 05	0.58502E 04	0.31069E 04	0.15079E 05	0.80879E 04	0.39567E 01	0.54167E-02
0.45650E 00	0.11154E 05	0.58623E 04	0.31121E 04	0.14516E 05	0.81677E 04	0.39788E 01	0.52992E-02
0.43575E 00	0.11116E 05	0.58741E 04	0.31158E 04	0.14062E 05	0.82588E 04	0.40043E 01	0.51748E-02
0.41500E 00	0.11057E 05	0.58857E 04	0.31177E 04	0.13588E 05	0.83487E 04	0.40310E 01	0.50435E-02
0.39425E 00	0.10979E 05	0.58970E 04	0.31178E 04	0.13094E 05	0.84378E 04	0.40588E 01	0.49057E-02
0.37350E 00	0.10880E 05	0.59081E 04	0.31162E 04	0.12580E 05	0.85262E 04	0.40877E 01	0.47619E-02
0.35275E 00	0.10761E 05	0.59191E 04	0.31126E 04	0.12047E 05	0.86142E 04	0.41175E 01	0.46122E-02
0.33200E 00	0.10620E 05	0.59299E 04	0.31069E 04	0.11495E 05	0.87018E 04	0.41479E 01	0.44567E-02
0.31125E 00	0.10457E 05	0.59406E 04	0.30990E 04	0.10924E 05	0.87892E 04	0.41788E 01	0.42956E-02
0.29050E 00	0.10272E 05	0.59512E 04	0.30886E 04	0.10335E 05	0.88768E 04	0.42100E 01	0.41288E-02
0.26975E 00	0.10063E 05	0.59618E 04	0.30754E 04	0.97266E 04	0.89646E 04	0.42413E 01	0.39561E-02
0.24900E 00	0.98283E 04	0.59723E 04	0.30591E 04	0.90998E 04	0.90528E 04	0.42725E 01	0.37772E-02
0.22825E 00	0.95662E 04	0.59829E 04	0.30391E 04	0.84543E 04	0.91417E 04	0.43034E 01	0.35918E-02
0.20750E 00	0.92743E 04	0.59934E 04	0.30149E 04	0.77900E 04	0.92316E 04	0.43338E 01	0.33993E-02
0.18675E 00	0.89492E 04	0.60041E 04	0.29854E 04	0.71068E 04	0.93228E 04	0.43634E 01	0.31988E-02
0.16600E 00	0.85866E 04	0.60149E 04	0.29497E 04	0.64043E 04	0.94158E 04	0.43919E 01	0.29895E-02
0.14525E 00	0.81805E 04	0.60258E 04	0.29058E 04	0.56822E 04	0.95109E 04	0.44190E 01	0.27699E-02
0.12450E 00	0.77227E 04	0.60370E 04	0.28514E 04	0.49400E 04	0.96089E 04	0.44446E 01	0.25384E-02
0.10375E 00	0.72011E 04	0.60485E 04	0.27826E 04	0.41771E 04	0.97106E 04	0.44682E 01	0.22924E-02
0.83000E 01	0.65970E 04	0.60605E 04	0.26928E 04	0.33924E 04	0.98172E 04	0.44894E 01	0.20285E-02
0.62250E 01	0.58785E 04	0.60733E 04	0.25699E 04	0.25850E 04	0.99309E 04	0.45081E 01	0.17415E-02
0.41500E 01	0.49825E 04	0.60871E 04	0.23873E 04	0.17529E 04	0.10055E 05	0.45237E 01	0.14229E-02

0.20750E-01 0.30948E 04 0.61041E 04 0.18508E 04 0.89444E 03 0.10208E 05 0.45353E 01 0.10817E-02
 0.50365E 04 0.61214E 04 0.24112E 04 0. 0.10366E 05 0.45481E 01 0.39109E-03

SUBCOOLING SECTION

TUBE FLUID TEMPERATURE	SHELL FLUID TEMPERATURE	TUBE I.D.	SHELL I.D.	BLOCKAGE	P/D	INCREMENTAL LENGTH	INCREMENTAL DP TUBE
0.12010E 04	0.10035E 04	0.33748E-00	0.46773E 01	0.33728E-00	0.16398E 01		
0.11600E 04	0.10020E 04	0.33457E-00	0.46570E 01	0.33538E-00	0.16444E 01	0.10286E-00	0.10646E-04
0.11190E 04	0.10004E 04	0.33083E-00	0.46308E 01	0.33294E-00	0.16505E 01	0.13190E-00	0.14311E-04
0.10780E 04	0.99892E 03	0.32558E-00	0.45942E 01	0.32948E-00	0.16591E 01	0.18527E-00	0.21456E-04
0.10370E 04	0.99740E 03	0.31661E-00	0.45315E 01	0.32347E-00	0.16744E 01	0.31669E-00	0.40763E-04
0.99605E 03	0.99589E 03	0.24052E-00	0.39998E 01	0.26784E-00	0.18401E 01	0.26852E 01	0.67776E-03

SUBCOOLING SECTION (CONTINUED)

TUBE FLUID TEMPERATURE	H TUBE	H SHELL	OVERALL HEAT TRANSFER COEFFICIENT U	N TUBE	N SHELL	RE TUBE	RE SHELL
0.83000E 00	0.83485E 04	0.55529E 04	0.27171E 04	0.18278E 05	0.61062E 04	0.38407E 01	0.80925E 00
0.86846E 04	0.55797E 04	0.27621E 04	0.18364E 05	0.62612E 04	0.38307E 01	0.59003E-02	0.78850E 00
0.90054E 04	0.56044E 04	0.28037E 04	0.18403E 05	0.64077E 04	0.38227E 01	0.59090E-02	0.76775E 00

TABLE 3
SAMPLE PRINTOUT

BLOCK 1

1 DESIGN CASE

N	M	KURVE=1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ICHANGE	IKON	ISCHRJ	ITFRAT	ITRATN	LIMIT	LIMITN
50	5	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	50	50	
		WTDOT	TINT	TOUTT		TOUTS		XINT		XOUTT							ALPHA1		ALPHA2				
		0.15930E 04	0.11750E 04	0.99605E 03		0.11500E 04		0.83000E 00		0.							0.10000E 01		0.10000E 01				
		WSDOT	TTS	TS		DT		TW		B							ZNT		PHUJ				
		0.78408E 04	0.56000E 00	0.35000E -01		0.68000E 00		0.35000E -01		0.50000E 00		0.37000E 02		0.33300E -00									
		PINI	ZNRD	RTW		RSW		RTS		AFUDGE		SIGMA		ZMOL									
		0.39500E 01	0.40000E 01	0.53500E 03		0.53500E 03		0.53500E 03		0.10000E 01		0.		0.39000E 02									
		GAMT	GAMS	DIMIN																			
		0.50000E 00	0.33600E -00	0.																			

1TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.118930E -00	0.20620E -00	0.21490E -00	0.21730E -00	0.21510E -00

2TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.140300E -01	0.43400E -01	0.46300E -01	0.49100E -01	0.51700E -01

3TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.169600E -02	0.74100E -02	0.80100E -02	0.84900E -02	0.89500E -02

4TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.118200E -00	0.18290E -00	0.18570E -00	0.19030E -00	0.19670E -00

5TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.144860E -02	0.43310E -02	0.41860E -02	0.40500E -02	0.39230E -02

6TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.44500E -00	0.36800E -00	0.33000E -00	0.30100E -00	0.27500E -00

7TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.21600E -02	0.20000E -02	0.18430E -02	0.16920E -02	0.15430E -02

8TH CURVE

0.85000E 03	0.10000E 04	0.11500E 04	0.13000E 04	0.14500E 04
0.10030E -01	0.10014E -01	0.99910E -00	0.99680E -00	0.99450E -00

9TH CURVE

0.85000E 03	0.10000E 04	0.11500E 04	0.13000E 04	0.14500E 04
0.30270E -02	0.29850E -02	0.29430E -02	0.29000E -02	0.28580E -02

10TH CURVE

0.85000E 03	0.10000E 04	0.11500E 04	0.13000E 04	0.14500E 04
0.83000E -00	0.76800E -00	0.70700E -00	0.64700E -00	0.60800E -00

11TH CURVE

0.85000E 03	0.10000E 04	0.11500E 04	0.13000E 04	0.14500E 04
0.27750E -02	0.28300E -02	0.28820E -02	0.29350E -02	0.29980E -02

12TH CURVE

0.94000E 03	0.11400E 04	0.13400E 04	0.15400E 04	0.17400E 04
0.90000E 03	0.87500E 03	0.84600E 03	0.80900E 03	0.76200E 03

13TH CURVE

0.90000E 03	0.95000E 03	0.10000E 04	0.10500E 04	0.11000E 04
0.11500E 04	0.12000E 04	0.12500E 04	0.13000E 04	0.13500E 04
0.11100E -02	0.16800E -02	0.25600E -02	0.37100E -02	0.52700E -02
0.72600E -02	0.99200E -02	0.13200E -01	0.17300E -01	0.22280E -01

14TH CURVE

0.41530E -00	0.65340E -00	0.10260E -01	0.15390E -01	0.22600E -01
0.32300E -01	0.45200E -01	0.61970E -01	0.83600E -01	0.11071E -02
0.90000E 03	0.95000E 03	0.10000E 04	0.10500E 04	0.11000E 04
0.11500E 04	0.12000E 04	0.12500E 04	0.13000E 04	0.13500E 04

15TH CURVE

0.80000E 03	0.10000E 04	0.12000E 04	0.14000E 04	0.16000E 04
0.30960E -02	0.31900E -02	0.32770E -02	0.33620E -02	0.34500E -02

BLOCK 2

CONDENSING SECTION

QUALITY	TUBE	FLUID	SHELL	FLUID	TUBE I.D.	SHELL I.D.	BLOCKAGE	P/D	INCREMENTAL LENGTH	NU SHELL
	TEMP	TEMP								
0.183000E 00	0.11756E 04	0.11500E 04	0.68000E 00	0.70706E 01	0.50000E 00	0.13468E 01			0.12042E 02	
0.180925E 00	0.11756E 04	0.11463E 04	0.65990E 00	0.69302E 01	0.49295E 00	0.13564E 01	0.70933E 00	0.12118E 02		
0.178850E 00	0.11752E 04	0.11427E 04	0.64172E 00	0.68032E 01	0.48637E 00	0.13655E 01	0.64167E 00	0.12191E 02		
0.176775E 00	0.11749E 04	0.11390E 04	0.62512E 00	0.66872E 01	0.48018E 00	0.13743E 01	0.58577E 00	0.12261E 02		
0.174700E 00	0.11747E 04	0.11353E 04	0.60986E 00	0.65806E 01	0.47433E 00	0.13828E 01	0.53880E 00	0.12328E 02		
0.172625E 00	0.11745E 04	0.11316E 04	0.59573E 00	0.64818E 01	0.46878E 00	0.13909E 01	0.49877E 00	0.12393E 02		
0.170550E 00	0.11744E 04	0.11280E 04	0.58257E 00	0.63899E 01	0.46349E 00	0.13988E 01	0.46425E 00	0.12456E 02		
0.168475E 00	0.11745E 04	0.11243E 04	0.57027E 00	0.63039E 01	0.45843E 00	0.14065E 01	0.43418E 00	0.12518E 02		
0.166400E 00	0.11746E 04	0.11206E 04	0.55872E 00	0.62232E 01	0.45358E 00	0.14140E 01	0.40774E 00	0.12578E 02		
0.164325E 00	0.11748E 04	0.11170E 04	0.54782E 00	0.61471E 01	0.44891E 00	0.14214E 01	0.38448E 00	0.12637E 02		
0.162250E 00	0.11750E 04	0.11133E 04	0.53752E 00	0.60751E 01	0.44441E 00	0.14285E 01	0.36377E 00	0.12694F 02	</td	

TABLE 4
Printout Nomenclature

<u>Symbol</u>	<u>Description</u>	<u>Dimensions</u>
CON LENGTH	length of condensing region	inches
DEQ SHELL	equivalent diameter of tube bank (on shell side)	inches
DP CON TOT	total pressure differential of tube fluid from entrance of tube to end of condensing region	psi
DP ENT TOT	entrance total pressure loss of tube fluid	psi
DP EXT TOT	exit total pressure loss of tube fluid	psi
DP SHELL CON	total pressure loss of shell fluid across length of condensing region	psi
DP SHELL IN	entrance total pressure loss of shell fluid	psi
DP SHELL OUT	exit total pressure loss of shell fluid	psi
DP SHELL SUB	total pressure loss of shell fluid across length of subcooling region	psi
DP SUB TOT	total pressure differential of tube fluid from beginning of subcooling region to the tube exit	psi
G SHELL	mass velocity of shell fluid at entrance of condensing region	lbs/hr ft ²
G TUBE	mass velocity of tube fluid at entrance of condensing region	lbs/hr ft ²
ID SHELL	shell inside diameter	inches
OD TUBE	tube outside diameter	inches
SHL FLUID WT	total weight of shell fluid inventory	lbs
SHL WALL WT	weight of shell wall	lbs
SUB LENGTH	length of subcooling region	inches
SUM DP SHELL	sum of shell fluid total pressure losses (including entrance and exit losses)	psi
SUM DP TUBE	total pressure differential of tube fluid from inlet manifold to exit manifold	psi
TOT LENGTH	combined length of condensing and sub- cooling regions	inches
TOTAL WT	combined weight of shell, tubes, tube- sheets and fluid inventories (does not include manifold weights)	lbs

TABLE 4 (Continued)

<u>Symbol</u>	<u>Description</u>	<u>Dimensions</u>
TUBE FLUID WT	total weight of tube fluid inventory	lbs
TUBE SHEET WT	total weight of tubesheets	lbs
TUBE WALL WT	total weight of tubes	lbs
V SHELL IN	velocity of shell fluid at shell entrance	ft/sec
V SHELL OUT	velocity of shell fluid at shell exit	ft/sec
V TUBE IN	vapor velocity at tube entrance	ft/sec

Note: Negative values of pressure differential denote a pressure rise,
positive values a pressure drop

TABLE 5
Printout Form - Constant Diameter

		<u>Condensing Section</u>				<u>Subcooling Section</u>			
tube fluid quality	tube fluid temp. (°F)	shell fluid temp. (°F)	shell fluid temp. (°F)	incremental length (inches)	tube fluid static pressure (psia)	tube fluid static pressure (psia)	tube fluid heat transfer coefficient (Btu/hr ft² °F)	shell fluid heat transfer coefficient (Btu/hr ft² °F)	shell fluid heat transfer coefficient (Btu/hr ft² °F)
<u>Condensing Section (Continued)</u>									
tube fluid quality	tube fluid Nusselt number	shell fluid Nusselt number	tube vapor full bore Reynolds number	incremental static pressure drop (psi)	tube fluid incremental static pressure drop (psi)	tube fluid incremental static pressure drop (psi)	tube fluid heat transfer coefficient (Btu/hr ft² °F)	shell fluid heat transfer coefficient (Btu/hr ft² °F)	shell fluid heat transfer coefficient (Btu/hr ft² °F)
<u>Subcooling Section (Continued)</u>									
tube fluid temp. (°F)	tube fluid Nusselt number	shell fluid Nusselt number	incremental length (inches)	transfer coefficient (Btu/hr ft² °F)	tube fluid Reynolds number	shell fluid Reynolds number	tube fluid incremental total pressure loss (psi)	shell fluid Reynolds number	tube fluid incremental total pressure loss (psi)
tube fluid temp. (°F)	tube fluid Nusselt number	shell fluid Nusselt number	incremental length (inches)	transfer coefficient (Btu/hr ft² °F)	tube fluid Reynolds number	shell fluid Reynolds number	tube fluid incremental total pressure loss (psi)	shell fluid Reynolds number	tube fluid incremental total pressure loss (psi)

TABLE 5 (Continued)
Printout Form - Tapered Diameter

<u>Condensing Section</u>						
tube fluid quality	tube fluid temp. (°F)	shell fluid condensing heat transfer coefficient (Btu/hr ft ² °F)	tube I. D. (inches)	shell I. D. (inches)	blockage ($\frac{\text{pitch}}{\text{diameter}}$) ratio	incremental length (inches)
<u>Condensing Section (Continued)</u>						
tube fluid quality	tube fluid condensing heat transfer coefficient (Btu/hr ft ² °F)	shell side heat transfer coefficient (Btu/hr ft ² °F)	tube vapor full bore Reynolds number	shell fluid Reynolds number	tube fluid static pressure (psi)	tube fluid incremental friction loss (psi)
tube fluid temp. (°F)	shell fluid temp. (°F)	tube I. D. (inches)	shell I. D. (inches)	blockage ($\frac{\text{pitch}}{\text{diameter}}$) ratio	incremental length (inches)	total pressure loss (psi)
<u>Subcooling Section</u>						
tube fluid temp. (°F)	tube fluid temp. (°F)	tube I. D. (inches)	shell I. D. (inches)	blockage ($\frac{\text{pitch}}{\text{diameter}}$) ratio	incremental length (inches)	tube fluid incremental total pressure loss (psi)
<u>Subcooling Section (Continued)</u>						
tube fluid temp. (°F)	tube fluid heat transfer coefficient (Btu/hr ft ² °F)	shell fluid heat transfer coefficient (Btu/hr ft ² °F)	shell fluid Nusselt number	tube fluid Reynolds number	shell fluid Reynolds number	tube fluid Reynolds number

APPENDIX 2

Methods of Calculating Condensing Heat Transfer
Coefficient

APPENDIX 2

Methods of Calculating Condensing Heat Transfer Coefficient

There are presently three methods of calculating condensing heat transfer coefficients built into the program. The option the program uses to calculate the condensing heat transfer coefficient is determined by the input.

Option I - Carpenter and Colburn Method

The condensing heat transfer coefficient is calculated using the following equations obtained from the Carpenter and Colburn correlation.

For turbulent film:

$$h_{\text{cond}} = 0.043 \Pr_L^{1/2} \frac{k_L \rho_L}{\mu_L} \sqrt{\tau_{\text{wall}} g_c}$$

For laminar film:

$$h_{\text{cond}} = k_L \left[\frac{\rho_L \tau_{\text{wall}} g_c}{2 \mu_L \Gamma} \right]^{1/2}$$

where: \Pr_L = Prandtl number of liquid
 k_L = thermal conductivity of liquid
 ρ_L = density of liquid
 μ_L = dynamic viscosity of liquid
 τ_{wall} = shear stress at wall
 g_c = Newton's conversion factor
 Γ = mass flow rate of condensate per unit of tube circumference

The wall shear stress is calculated using the Lockhart and Martinelli two-phase flow pressure loss correlation. In order to calculate condensing heat transfer coefficients using the Carpenter and Colburn method, input a value of one (1) for IKON in the proper column of control card.

Option II - Film Conduction Method, Transition Criterion of Lockhart and Martinelli

A condensing heat transfer coefficient is calculated assuming that there is a linear temperature profile across the liquid film and that the liquid film thickness can be calculated using the Lockhart and Martinelli liquid fraction correlation. This result is then multiplied by a constant to adjust the calculated value to give closer agreement with experimentally determined condensing heat transfer coefficients.

$$h_{\text{cond}} = AFUDGE \frac{k_L}{\delta_L}$$

where: δ_L = liquid film thickness = $\frac{D_i}{2} (1 - \sqrt{1 - R_L})$
 D_i = inside diameter of tube
 R_L = Lockhart and Martinelli liquid fraction

To use this option input a two (2) in the column of the control card marked IKON. A value of 0.3 for AFUDGE (see data cards) has been found to give reasonable agreement with existing condensing data for potassium when the Schrage effect is excluded from the calculation. A value of 1.0 for AFUDGE should be used if the Schrage effect is to be included.

Option III - Film Conduction Method, Transition Criterion of Rohsenow

This option calculates condensing coefficient in a manner similar to that of Option II. The only difference is that the liquid film flow regime of Lockhart and Martinelli is based upon Rohsenow's transition criterion described in Report PWA-2320, Volume 1, Section IV. D. To use this method input a three (3) in the column of the control card marked IKON.

Schrage Effect

The condensing heat transfer coefficient is calculated assuming that there are two resistances to the flow of heat from the vapor core to the wall (Schrage effect):

1. The liquid film, and
2. The interface between the vapor core and the liquid film.

This is accounted for by calculating separate heat transfer coefficients for the film and for the interface by the expression

$$h_{\text{cond}} = \frac{1}{\frac{1}{h_{\text{film}}} + \frac{1}{h_{\text{Schrage}}}}$$

h_{film} is calculated in accordance with the option chosen (I, II, or III).

h_{Schrage} is calculated from the relation

$$h_{\text{Schrage}} = \left(\frac{\sigma}{2 - \sigma} \right) \left(\frac{2g}{\pi} \right)^{1/2} \left(\frac{M}{R} \right)^{3/2} \left(\frac{P_v \lambda^2}{T_v^{5/2}} \right)$$

where: R = universal gas constant
M = molecular weight
 P_v = saturation pressure
 T_v = saturation temperature (absolute)
 λ = latent heat of vaporization
 σ = SIGMA = (number of molecules striking interface which condense)/(total number of molecules striking surface)

Recommended values of SIGMA range between 0.0168 and 0.045 to show agreement with existing condensing potassium heat transfer data.

Input Arrangement for Schrage Effect

To include the Schrage effect in the calculations, input a one (1) for ISCHRJ in the proper control card column and input values of SIGMA and ZMOL in the proper data card location. If Schrage effect is not to be included, input a zero (0) for ISCHRJ and omit input for SIGMA and ZMOL.

APPENDIX 3

Definitions of Blockage, Tube Entrance
Loss Coefficient Modifier, Number of
Tube Rows, Tube Taper, Shell Taper,
Shell Entrance and Exit Pressure Loss Coefficients

APPENDIX 3

Definitions of Blockage, Tube Entrance Loss Coefficient Modifier, Number of Tube Rows, Tube Taper, Shell Taper, and Shell Entrance and Exit Pressure Loss Coefficients

Blockage

The blockage B is defined as the ratio of blocked area of the shell-side fluid to the frontal area of the shell, $(\text{total cross-sectional area of tubes}) / (\text{frontal area of shell})$. The maximum permissible blockage is $\frac{\pi}{2\sqrt{3}}$ which corresponds to the blockage when tubes arranged in a hexagonal pattern have interference.

Tube Entrance Loss Coefficient Modifier

The tube entrance loss coefficient modifier PHUJ is defined as a factor C which accounts for the effect of a rounded inlet in the tube entrance losses in the equation

$$P = CK \frac{\rho V^2}{2g_c}$$

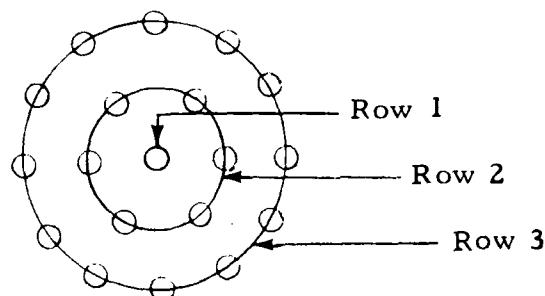
Where $\frac{\rho V^2}{2g_c}$ = velocity head of fluid at tube entrance

K = total pressure loss coefficient for sharp-edged sudden contraction (a function of area ratio and Reynolds number, calculated within the program)

Figure 1 indicates the values of the factor C as a function of the radius of rounding divided by the tube diameter.

Number of Tube Rows

Number of tube rows is defined as the number of concentric circles or hexagons on which the tubes are spaced (including the tube located at the center) as illustrated in the sketch.



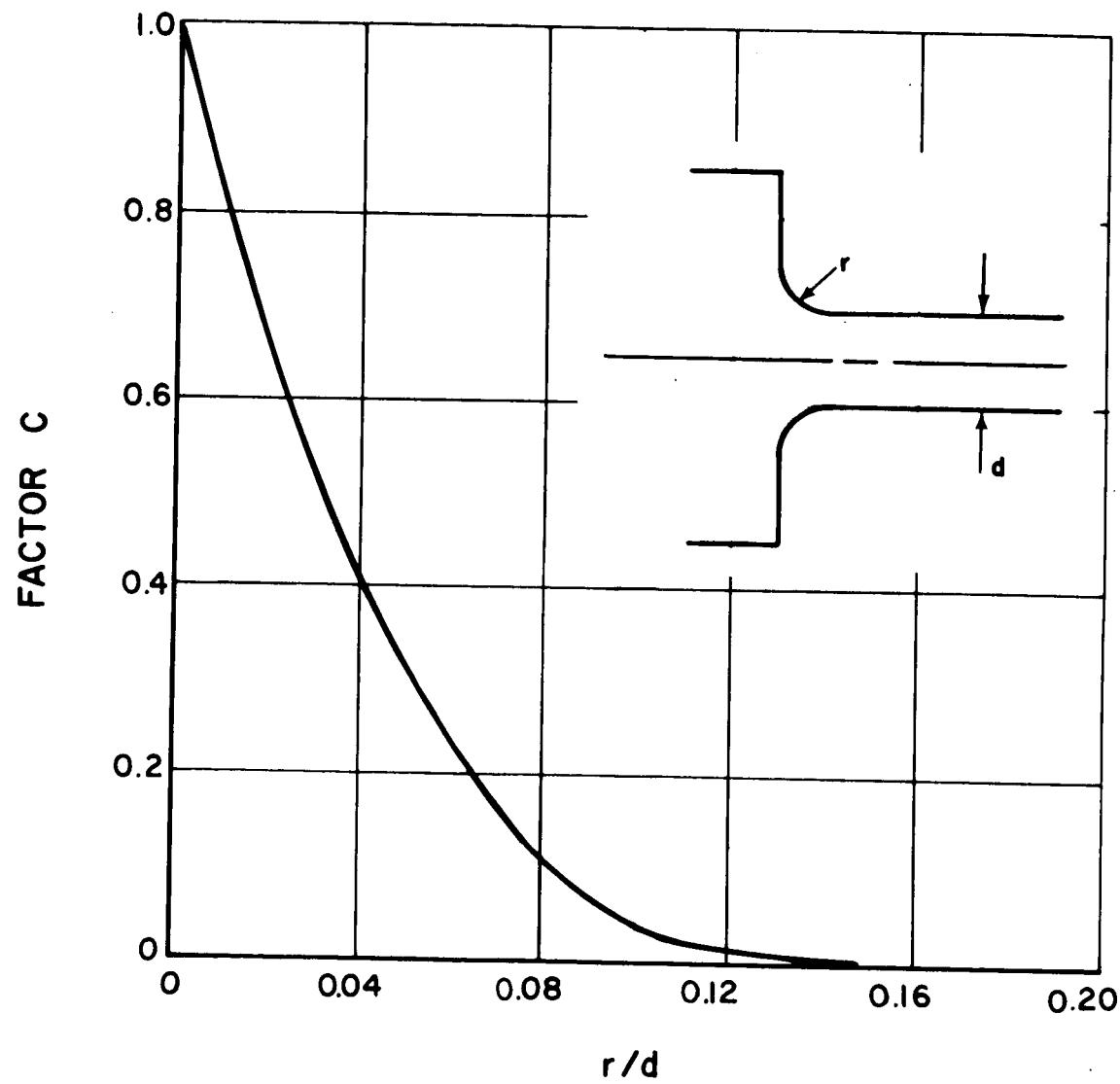
REF. CURTISS WRIGHT CORPORATION
REPORT R-109

Figure 1 Contraction Pressure Loss Coefficient to Account for Rounded Inlets

Tube Taper

The tube taper GAMT is defined as the per cent decrease of tube inside diameter per unit of condenser length (1/ft). Therefore for a tube of linearly tapered diameter, the tube inside diameter at any point is determined by

$$D_{\ell} = D_0 [1 - (GAMT) (\ell)]$$

where ℓ = distance from condenser entrance

D_0 = tube inside diameter at condenser entrance

D_{ℓ} = tube inside diameter at a location ℓ feet from entrance

Shell Taper

The shell taper GAMS is the per cent decrease of shell inside diameter per unit of condenser length (1/ft). For a shell of linearly tapered diameter, the shell inside diameter at any point ℓ feet from the entrance is determined by

$$(SD)_{\ell} = (SD)_0 [1 - (GAMS) (\ell)]$$

where ℓ = distance from condenser entrance

$(SD)_0$ = shell inside diameter at condenser entrance

For constant diameter heat exchangers, set GAMT = 0.0 and GAMS = 0.0

Shell Entrance Pressure Loss Coefficient

The shell entrance pressure loss coefficient ALPHA 1 is defined as the total pressure loss due to expansions and contractions of the shell-side fluid, expressed in terms of the number of velocity heads calculated from the shell fluid velocity and density at the entrance of the shell. The following types of pressure drop can be calculated by use of a properly selected value of ALPHA 1

- 1) Expansion loss from feed pipe or pipes to the inlet manifold,
- 2) Loss through orifice separating inlet manifold and shell,
- 3) Loss due to radial flow between tubesheet and orifice plate (see Report PWA-2320, Volume 1, Section IV.E., Appendix E), and
- 4) Loss through an orifice plate.

The value of ALPHA 1 is the sum of the loss coefficients associated with each type of loss when modified to account for area ratios. For example a typical pressure loss for flow of a liquid through an orifice is 2.78 velocity heads based upon the orifice flow area. Thus, to properly use this information in determining ALPHA 1, the coefficient 2.78 must be multiplied by the square of the ratio of orifice flow area to the flow area at the shell entrance. Report PWA-2320 discusses references for various loss coefficients in Section IV. E.

Shell Exit Pressure Loss Coefficient

The shell exit pressure loss coefficient ALPHA 2 is defined similarly to ALPHA 1 except that the velocity head is calculated from the shell fluid velocity and density at the exit of the shell.

APPENDIX 4

Error Printouts

APPENDIX 4

Error Printouts

The program contains numerous tests to stop a case in the event that an attempt is made to design a physically impossible condenser. If a case is terminated in this manner, an error printout occurs. Error printouts indicate why the case was terminated and, in many instances, include the results calculated up to the time the program stopped.

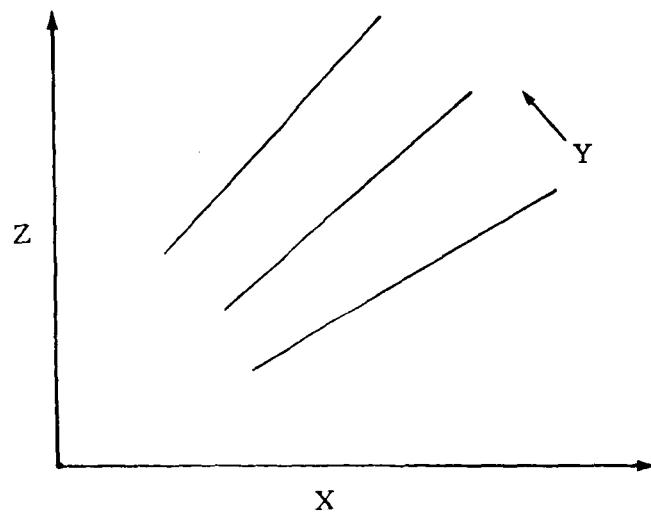
Error printouts occur if:

- 1) The value of an independent variable is beyond the range of an input property curve,
- 2) A negative incremental length is calculated,
- 3) An incremental length is calculated to be zero,
- 4) An imaginary incremental length is calculated (the square root of a negative number enters into the calculation),
- 5) The program fails to converge on increment length,
- 6) The calculated temperature out of the condensing section is less than or equal to the input tube fluid exit temperature,
- 7) The tube fluid temperature is less than or equal to the shell fluid temperature at an axial location,
- 8) A case having a tapered shell with constant diameter tubes is input,
- 9) A case having no condensing section ($XINT = 0.0$) is input,
- 10) Tube diameter is less than the input minimum diameter $DIMIN$ (see data cards)
- 11) The shell diameter is too small (the tubes have interference - i.e.,
blockage $> \frac{\pi}{2\sqrt{3}}$

If termination is caused by Item 1, the error printout will indicate the location (program statement number) where the curve-reading subroutine was used. In addition, the value of the independent variable that was off-scale is printed. This error printout also lists a KK number indicating at which end of the scale the curve was out of range. KK = 1 indicates that the independent variable was less than the minimum input value. KK = 2 indicates that the independent variable was greater than the maximum input value.

If termination is caused by an excessive taper (Items 10 and/or 11) the printout will list GAMS, GAMT, DL2, and DLN1. DL2 and DLN1 are the last values of the last incremental lengths calculated during the iteration routines. DL2 corresponds to the last calculated incremental length in the condensing region and DLN1 corresponds to that of the subcooling region. These incremental lengths are printed out in units of feet instead of inches, as in the main printout. If the reason for termination is Item 10, the value printed for GAMT will be one-half the input value and GAMS is printed out as the input value. If the reason for termination is Item 11, the value printed for GAMS will be one-half the input value and GAMT is printed out as the input value. The comparison of these values with the input values of GAMS and GAMT allows the analyst to determine which of the two tapers (or both) caused the error.

In calculating the shell-side heat transfer coefficients, a bivariate fit of shell-side Reynolds number X and pitch-to-diameter ratio Y is used to obtain eddy diffusivity of momentum divided by kinematic viscosity $\epsilon_m/v = Z$. If the X and/or Y values are off-scale (see sketch), the program will not stop but will use an appropriate end-point value from the bivariate fit. The shell fluid Reynolds number (X value), an error number (ignore), the program statement number where the bivariate fit is being used, and a KK value to indicate where the curve had insufficient range, are all printed out.



These values appear ahead of the printout line for the increment for which the calculations were being performed in Block 2. More than one error printout of a kind can occur for a particular increment on tapered condensers, especially when the iterative procedure is used. In addition, more than one kind of error can occur in the calculation for a particular increment.

The pertinent program statement numbers for bivariant fit errors are:

- 1) 611 refers to the condensing region for a tapered case,
- 2) 613 refers to the inlet of an increment in the condensing region (constant-diameter case),
- 3) 615 refers to the exit of an increment in the condensing region (constant-diameter case),
- 4) 1760 refers to the inlet of an increment in the subcooling region (constant-diameter case),
- 5) 1762 refers to the exit of an increment in the subcooling region (constant-diameter case), and
- 6) 1764 refers to the subcooling region for a tapered case.

The KK values for the bivariant fit error printouts are

KK1	off-scale at X minimum
KK2	off-scale at X maximum
KK3	off-scale at Y minimum
KK4	off-scale at X minimum and Y minimum
KK5	off-scale at X maximum and Y minimum
KK6	off-scale at Y maximum
KK7	off-scale at X minimum and Y maximum
KK8	off-scale at X maximum and Y maximum

APPENDIX 5

List of Computer Statements

```

CWE1885 CALL DK1885
CALL EXIT
CALL DUMP
END CSUB1885I      DK1885
SUBROUTINE DK1885
EQUIVALENCE (CURVE(
1   (CURVE( 1) • C1CPTV(1)) • (CURVE( 14) • C3UTV (1)) •
2   (CURVE( 27) • C4KTV (1)) • (CURVE( 40) • C5CPTL(1)) •
(CURVE( 53) • C6RTL (1)) • (CURVE( 66) • C7UTL (1)) •
(CURVE( 79) • C8KTL (1)) • (CURVE( 92) • C9CPS (1)) •
(CURVE(105) • C10RS (1)) • (CURVE(118) • C11US (1)) •
(CURVE(131) • C12KS (1)) • (CURVE(144) • C14ZAM(1)) •
(CURVE(157) • C2RTV (1)) • (CURVE(180) • C13PIN(1)) •
(CURVE(203) • C16KTw(1)) • (CURVE(216) • CURVES(1)) •
7   EQUIVALENCE (BLK (27) • WTDCT (27) • TINT (26) • TOUTT (25) •
TOUTS (24) • XINT (23) • XOUTT (22) • ALPHA1 (21) •
ALPHA2 (20) • WSDOT (19) • TTS (18) • TS (17) •
DT (16) • TW (15) • B (14) • ZNT (13) •
PHUJ (12) • PINT (11) • ZNRO (10) • RTW ( 9) •
RSW ( 8) • RTS ( 7) • AFUDGE ( 6) • SIGMA ( 5) •
ZMOL ( 4) • GAMT ( 3) • GAMS ( 2) • DIMIN ( 1) •
EQUIVALENCE (ANS( 1) • ZDO ( 1) • (ANS( 2) • ZDE ( 1) • (ANS( 3) • ZDS ( 1) •
(ANS( 4) • GS ( 1) • (ANS( 5) • GT ( 1) • (ANS( 6) • VTSAVE) •
(ANS( 7) • VS1 ( 1) • (ANS( 8) • VS2 ( 1) • (ANS( 9) • ZTOTLT) •
2   (ANS(10) • ZLTCON) • (ANS(11) • ZLTSUB) • (ANS(12) • SPPTTOT) •
(ANS(13) • PTENTT) • (ANS(14) • SDPTTOT) • (ANS(15) • SDPTNM) •
(ANS(16) • DPTEXT) • (ANS(17) • DPSTOT) • (ANS(18) • DPSIN) •
(ANS(19) • SDPSIN) • (ANS(20) • SDPSNM) • (ANS(21) • DPSOUT) •
(ANS(22) • ZMTOT) • (ANS(23) • ZMTF) • (ANS(24) • ZMSF) •
(ANS(25) • ZMT ( 1) • (ANS(26) • ZMS ( 1) • (ANS(27) • ZMTS ( 1) •
8   COMMON C1CPTV, C3UTV, C4KTV, C5CPTL, C6RTL, C7UTL, C8KTL,
C9CPS, C10RS, C11US, C12KS, C14ZAM, C2RTV, C13PIN, C16KTw, CURVES, CURVE, C19RES, BLK, ANS
2   COMMON TABLE, TABOUT, BUFX, BUFX, ITABLE
DIMENSION C1CPTV(13), C2RTV (23), C3UTV (13), C4KTV (13), C5CPTL(13),
1   C6RTL (13), C7UTL (13), C8KTL (13), C9CPS (13), C10RS (13),
2   C11US (13), C12KS (13), C15KTw(13),
3   CURVE(15), ANS(99), C13PIN(23), C14ZAM(13), C19RES(61),
4   KURVE(15), ANS(99), C13PIN(23), C14ZAM(13), C19RES(61),
DIMENSION SAVBK(1000), SVBK(1000)
P1=3•141592653589
FDPI=1•2732395
PID4=.7853981633397

```

```

BMAX = PI / 3.4641
G=32.17405
GK=G*2.592E7
ZLC=12.0
TC=3600.
MM = 3
NN = 2
      WRITE OUTPUT TAPE NN, 1003
      READ INPUT TAPE MM, 2, HOLL
      WRITE OUTPUT TAPE NN, 2, HOLL
      READ INPUT TAPE MM, 3,N,M, (KURVE(I), I=1,15), ICHANG, IKON, ISCHRJ,
1ITERAT,ITRATN,LIMIT,LIMITN
      LIQUID = 1
      IFRITZ = 1
      DL2 = 0.0
      DLN1 = 0.0
      TOTLT = 0.0
      SLTCON = 0.0
      SLTSUB = 0.0
      PINTZ = 0.0
      ERROR = 0.0
      KILL = 0
      IF (N) 1000,7,7
      IF (ICHANG) 4,5,4
      READ INPUT TAPE MM,6,(BLK(I), I=1,27)
      GO TO 10
      4   READ INPUT TAPE MM,8,I, TEMPER
      IF (I) 10,10,9
      BLK(I)=TEMPER
      9   GO TO 4
      10  WRITE OUTPUT TAPE NN,11,N,M, (KURVE(I), I= 1,15), ICHANG, IKON, SCHR
          1J,ITERAT,ITRATN,LIMIT,LIMITN
          WRITE OUTPUT TAPE NN,12,(BLK(I), I=1,27)
          DO 110 I=1,27
          110  ANS(I)=0.0
              DTZLC=DT/ZLC
              DO 270 I=1,12
                  L1=13*LIQUID+78*I-90
                  CURVES(L1)=10*I+LIQUID

```

```

CURVES(L1+1)=5.
CURVES(L1+2)=0.
L4=L1+3
L13=L4+9
1F (KURVE(I)) 272,271,272
272 READ INPUT TAPE MM, 6, (CURVES(K), K=L4,L13)
      WRITE OUTPUT TAPE NN, 687,1
      WRITE OUTPUT TAPE NN, 6, (CURVES(K), K=L4,L13)
271 J=13*(I-1)
      DO 273 K=L1,L13
      J=J+1
      CURVE(J)=CURVES(K)
CONTINUE
273 CONTINUE
270 CONTINUE
      L138 = 914
      DO 681 I = 13,14
      L1 = 23*L1QUID + L138
      CURVES(L1) = 10*I+LIQUID
      CURVES(L1+1) = 10.
      CURVES(L1+2) = 0.
      L4 = L1 + 3
      L23= L4 + 19
1F (KURVE(I)) 685,686,685
685 READ INPUT TAPE MM, 6, (CURVES(K), K= L4,L23)
      WRITE OUTPUT TAPE NN, 687,1
      WRITE OUTPUT TAPE NN, 6, (CURVES(K), K= L4,L23)
687 FORMAT(1H0,12,8HTH CURVE)
686 J = 156 + 23 * (I - 13)
      DO 688 K = L1,L23
      J = J+1
      CURVE(J)= CURVES(K)
CONTINUE
      L138 = 1052
688 CONTINUE
      L138 = 1052
681 CONTINUE
      DO 274 I = 15,15
      L1 = 13*I + 1200
      CURVES(L1)=10*I
      CURVES(L1+1)=5.
      CURVES(L1+2)=C.

```

```

L4=L1+3          00123
L13=L4+9         00124
IF (KURVE(I))275,276,275
 275 READ INPUT TAPE MM, 6, (CURVES(K), K=L4,L13)
      WRITE OUTPUT TAPE NN, 687,1
      WRITE OUTPUT TAPE NN, 6, (CURVES(K), K= L4,L13)
 276 J = 202
      DO 277 K=L1,L13
      J= J+1
      CURVE(J)=CURVES(K)
      CONTINUE
 277 CONTINUE
 274 CONTINUE
      DO=DTZLC+TW/6.0
      DODT=DC/DTZLC
      DE=DC/B*(1.0-B)
      DEXT = DTZLC
      DETNN = DTZLC
      BMTWC = (1.0/DODT)**2*B
      BMTWE = BMTWC
      PINTS = 0.0
      SDPSTA = 0.0
      TINSAV = TINT
      PINSAV = PINT
      POD = SQRTF(P1 /2.0/732051)
      DS = POD * (2.0 * ZNRO -1.0)* DO
      BMTW = BMTWC
WTDNT=WTDOT/ZNT
GT=FDPI/DTZLC**2*WTDNT
 1501 IF (XINT) 9019.9019*1502
      CALL UNBAR (C3UTVA,1,TINSAV,0.0,UTVA,KK)
      IF (KK) 1600.1601,1600
 1600 X=TINSAV
      ERROR = C3UTV(1)
      LOC = 1600
      GO TO 9000
 1601 RETA = FDPI / DTZLC * XINT / UTVA * WTDNT
      IF (RETA = 1000.) 1503,1504*1505
 1503 WRITE OUTPUT TAPE NN, 141,RETA
      RETA = 1000.

```

```

GO TO 1504
1505 IF (RETA - 1000000.) 1504.1504.1506
1504 ZKC = -.4 * BMTW - LOGF(RETA)/50.2 + .68
GO TO 1507
1506 ZKC =-.4 * BMTW + .405
1507 CALL UNBAR (C2RTV,1,TINSAV,0.0,RTVA,KK)
IF (KK) 1602,1603,1602
1602 X = TINSAV
ERROR = C2RTV(1)
LOC = 1602
GO TO 9000
1603 DUMP = GT * GT / GK
DUMP1 = 1.0 - B*B*(DTZLC /DO)**4.
PTENTT = DUMP / RTVA * PHUJ * ZKC /144.
PTENTS = DUMP / RTVA * PHUJ *(ZKC + DUMP1)/144.
PINTS = PINT - PTENTS
PINTZ = PINTS
CALL UNBAR (C13PIN,1,PINTS,0.0,TINT,KK)
IF (KK) 1608,2610,1608
1608 X = PINTS
ERROR = C13PIN(1)
LOC = 1608
GO TO 9000
2610 CALL UNBAR (C14ZAM,1,TINT,0.0,ZAMBDA,KK)
IF (KK) 1609,998,1609
1609 X = TINT
ERROR = C14ZAM(1)
LOC = 1609
GO TO 9000
998 CALL UNBAR (C5CPCTL,1,TINT .0.0,CPINT ,KK)
15 X=TINT
ERROR=C5CPCTL(1)
LOC=15
GO TO 9000
16 CALL UNBAR (C5CPCTL,1,TOUUTT .0.0,CPOUTT,KK)
IF (KK) 17,18,17
17 X=TOUUTT
ERROR=C5CPCTL(1)

```

```

LOC=17
GO TO 9000
CPTBAR=(CPINT+CPOUTT)/2.0
CALL UNBAR (C9CPS •1•TOUTS ,0.0,CPSOUT,KK)
IF (KK) 21,163,21
21 X=TOUTS
ERROR=C9CPS (1)
LOC=21
GO TO 9000
CALL UNBAR (C2RTV ,1•TINT •0.0,RTV ,KK)
DUR=RTV
IF (KK) 13,14,13
ERROR=C2RTV (1)
LOC=13
GO TO 9000
14 VTSAVE = FDPI/RTV *WTDOT/ZNT*.04/DT***2
DSUDO = DO * (ZNT/B)**.5
GS = FDPI * WSDOT /(ZNT * DO * DO ) * B /((1. - B )
ZNTB=(1.0/(ZNT*B))**.5
GTE = GT
GSIN = GS
SHELEX = DSUDO
GSOUT = GS
START OF 100 SERIES.
TS1=TOUTS
TS2=TS1
K=0
I=0
X1=XINT
TT1=TINT
TT2=TT1
DX=((XINT-XOUTT)/FLOATF(N)
SDPS1N=0.0
SLTCON=0.0
WME=0.0
ITAPER = 1
DIO = DTZLC

```

```

DSO = DSUDO          00240
ICOUNT = 0           00241
IF (GAMS +GAMT) 501,118,501
ITAPER = 2           00242
IF (GAMT) 118,9003,118
K=K+1               00243
IF (N-K) 119,24,24   00244
X2=X1-DX            00245
IF (X2) 610,610,620 00246
X2 = 0.              00247
CALL UNBAR (C9CPS .1,TS1 ,0,0,CPS1 ,KK) 00248
IF (KK) 25,26,25    00249
X=TS1                00250
ERROR=C9CPS (1)     00251
LOC=25               00252
GO TO 9000           00253
TS2=TS1-ZAMBDA/WSDOT*WTDOT/CPS1*DX 00254
CALL UNBAR (C11US .1,TS1 ,0,0,US1 ,KK) 00255
IF (KK) 23,27,23    00256
X=TS1                00257
ERROR=C11US (1)     00258
LOC=25               00259
GO TO 9000           00260
CALL UNBAR (C11US .1,TS2 ,0,0,US2 ,KK) 00261
IF (KK) 28,1327,28   00262
X=TS2                00263
ERROR=C11US (1)     00264
LOC=28               00265
GO TO 9000           00266
IF (TT1 - TS1) 9015,9016,29 00267
GO TO (503,504), ITAPER 00268
RES1 = DE * GS /US1 00269
RES2 = DE * GS /US2 00270
GO TO 31             00271
DL2 = 0.0             00272
USX= US1             00273
DL20. = DL2           00274
DIX = D10 * ( 1.- GAMT *(SLTCON + DL2 ) ) 00275
DOX = D1X + TW / 6.   00276
                                         00277
                                         00278

```

```

SUDOX=DSO * (1.- GAMS * (SLTCON + DL2))
GSX = FDP1 * WSDOT /(SUDOX**2 - ZNT * DOX ** 2)
IF(DIX - DIMIN /12.0) 506,506,507
506 GAMT = GAMT * .5
KILL = 1
ERROR = 1.0
LOC = 100
507 IF (SUDOX-DOX * SQRTF(ZNT/BMAX)) 508,508,509
508 GAMS = GAMS *.5
KILL = 1
ERROR = ERROR + 2.0
LOC = 100
509 IF(KILL) 510,510, 9100
510 DESX =(SUDOX**2 - ZNT * DOX** 2)/(ZNT * DOX )
DETX = DIX
RESX = DESX * GSX /USX
IF((ICOUNT) 31,31,161
31 CALL UNBAR (C12KS ,1,TS1 ,0.0,ZKS1 ,KK)
IF(KK) 32,33,32
32 X=TS1
ERROR=C12KS (1)
LOC=32
GO TO 9000
33 CALL UNBAR (C12KS ,1,TS2 ,0.0,ZKS2 ,KK)
IF (KK) 34,35,34
34 X=TS2
ERROR=C12KS (1)
LOC=33
GO TO 9000
35 CALL UNBAR (C9CPS,1,TS2,0.0,CPS2,KK)
IF (KK) 160,161,160
160 X=TS2
ERROR=C9CPS (1)
LOC=160
GO TO 9000
161 GO TO (511,512) *ITAPER
512 IF((ICOUNT) 513,513,514
513 ZKSX = ZKS1
CPSX = CPS1
00279
00280
00281
00282
00283
00284
00285
00286
00287
00288
00289
00290
00291
00292
00293
00294
00295
00296
00297
00298
00299
00300
00301
00302
00303
00304
00305
00306
00307
00308
00309
00310
00311
00312
00313
00314
00315
00316
00317

```

```

RESPC1 = RESX          00318
DESPC1 = DESX          00319
DETPC1 = DEX           00320
SUDOX1 = SUDOX         00321
GSOUTS = GSX           00322
      PRSX = USX * CPSX /ZKSX 00323
      BX = DOX ** 2 * ZNT / SUDOX**2 00324
      PODX = SQRTF(P1/3•464/BX) 00325
      CALL SHELLS (RESX•PRSX•PODX, ZNUSX, C19RES, KK)
      IF (KK) 611•612•611 00326
      X = RESX           00327
      ERROR = C19RES(1) 00328
      LOC = 611           00329
      WRITE OUTPUT TAPE NN, 9001•X•ERROR•KK•LOC 00330
      HSX = ZNUSX * ZKSX / DESX 00331
      IF (ICOUNT) 516 •516 • 60 00332
      PRS1 = CPS1 * US1 /ZKS1 00333
      PRS2=CPS2/ZKS2*US2 00334
      CALL SHELLS (RES1•PRS1•POD, ZNUS1, C19RES, KK)
      IF (KK) 613•614•613 00335
      X = RES1           00336
      ERROR = C19RES(1) 00337
      LOC = 613           00338
      WRITE OUTPUT TAPE NN, 9001•X•ERROR•KK•LOC 00339
      CALL SHELLS (RES2•PRS2•POD, ZNUS2, C19RES, KK)
      IF (KK) 615•616•615 00340
      X = RES2           00341
      ERROR = C19RES(1) 00342
      LOC = 615           00343
      WRITE OUTPUT TAPE NN, 9001•X•ERROR•KK•LOC 00344
      HS1 = ZNUS1 * ZKS1 / DE 00345
      HS2 = ZNUS2 * ZKS2 / DE 00346
      X = TT1             00347
      CALL UNBAR (C3UTV •1•TT1, 0•0•UTV1 •KK) 00348
      IF (KK) 36•37•36 00349
      ERROR=C3UTV (1) 00350
      LOC=36             00351
      GO TO 9000          00352

```

C

```

37 CALL UNBAR (C2RTV .1,TT1 ,0,0,RTV1 ,KK)
IF (KK)38,39,38
  ERROR=C2RTV (1)
LOC=38
GO TO 9000
39 CALL UNBAR (C7UTL .1,TT1 ,0,0,UTL1 ,KK)
IF (KK)40,41,40
  ERROR=C7UTL (1)
LOC=40
GO TO 9000
41 CALL UNBAR (C6RTL .1,TT1 ,0,0,RTL1 ,KK)
IF (KK)42,43,42
  ERROR=C6RTL (1)
LOC=42
GO TO 9000
42 CALL UNBAR (C8KTL .1,TT1 ,0,0,ZKTL1 ,KK)
IF (KK)44,45,44
  ERROR=C8KTL (1)
LOC=44
GO TO 9000
43 CALL UNBAR (C5CP TL .1,TT1 ,0,0,CPTL1 ,KK)
IF (KK)46,47,46
  ERROR=C5CP TL (1)
LOC=46
GO TO 9000
44 CALL UNBAR (C5CP TL .1,TT1 ,0,0,CPTL1 ,KK)
IF (KK)46,47,46
  ERROR=C5CP TL (1)
LOC=46
GO TO 9000
45 CALL UNBAR (C5CP TL .1,TT1 ,0,0,CPTL1 ,KK)
IF (KK)46,47,46
  ERROR=C5CP TL (1)
LOC=46
GO TO 9000
46 IF (1)447,447,485
  REMVX = WTDNT * FDPI / DTZLC
  RELIN = REMVX * (1. - XINT) / UTL1
  REGIN = REMVX * XINT / UTV1
  IF (RELIN - 1000.) 448,449,449
    IF (REGIN - 1000.) 450,451,451
    IF (REGIN - 1000.) 452,453,453
  CXIN = (RELIN/REGIN*RTV1/RTL1)**.5*UTL1/UTV1
  GO TO 454
451 CXIN = (347.826*RTV1/RTL1)**.5*(UTL1/UTV1)*RELIN**.5/REGIN**.9
  GO TO 454
452 CXIN = (.002875*RTV1/RTL1)**.5*(UTL1/UTV1)*RELIN**.9/REGIN**.5
  GO TO 454
453 CXIN = UTL1/UTV1*(RELIN/REGIN)**.9*(RTV1/RTL1)**.5

```

```

454 XP = .299 * CXIN ** .756
RLIN = XP / (1.0 + XP)
RGIN = 1.0 - RLIN
DNSVIN = RTV1
DNSLIN = RTL1
AINT = PID4 * DTZLC * DTZLC
485 GO TO (517•518)•1 TAPER .
518 GO TO (301•303•305) •IKON
301 CALL CARCOL (X1•WTDNT/TC•DIX•UTV1/TC•RTV1•UTL1/TC•RTL1•ZKTL1/TC•
1CPTL1•HTX•SMW1)
GO TO 399
303 CALL LMCOND (X1•WTDNT/TC•AFUDGE ,
1UTV1/TC•UTL1/TC•RTV1•RTL1• CPTL1• HTX•SMW1)
GO TO 399
305 CALL ALMCON (X1•WTDNT/TC•AFUDGE ,
1RTV1•RTL1•CPTL1•HTX•SMW1)
399 IF (ISCHRJ) 350•398•350
350 TVAP = TT1 + 460•
HSCHRJ = 30000.*SIGMA/(2.0-SIGMA)* PINTS * ZMOL**1.5*ZAMBDA**2.
1 TVAP ** 2.5
HTX = 1.0/(1.0/HTX + 1.0/HSCHRJ)
398 IF (1) 121•519•121
519 RET1 = FDPI * X1 / DIX * WTDNT / UTV1
HT1 = HTX
HS1 = HSX
ZNUSI = ZNUSX
GO TO 121
517 GO TO (320•322•324)•IKON
320 CALL CARCOL (X1•WTDNT/TC•DTZLC•UTV1/TC•RTV1•UTL1/TC•RTL1•
1 ZKTL1/TC•CPTL1•HT1•SMW1)
GO TO 499
322 CALL LMCOND (X1•WTDNT/TC•AFUDGE•ZKTL1•DTZLC•UTV1/TC•UTL1/TC•
1 RTV1•RTL1•CPTL1•HT1•SMW1)
GO TO 499
324 CALL ALMCON (X1•WTDNT/TC•AFUDGE•ZKTL1•DTZLC•UTV1/TC•UTL1/TC•
1 RTV1•RTL1•CPTL1•HT1•SMW1)
499 IF (ISCHRJ) 351•498•351
351 TVAP = TT1 + 460•
HSCHRJ = 30000.*SIGMA/(2.0-SIGMA)*PINTS*ZMOL**1.5*ZAMBDA**2.

```

```

1   /TVAP **2.5
    HT1 = 1.0/(1.0/HT1 + 1.0/HSCHRJ)
498  IF (I) 121,120,121
120  RET1=FDPI/DTZLC*X1/UTV1*WTDNT
121  UTV2 = UTV1
      RTV2 = RTV1
      UTL2 = UTL1
      RTL2 = RTL1
      ZKTL2 = ZKTL1
      CPTL2 = CPTL1
      CALL UNBAR (C16KTW•1•TT1 •0•0•ZKTW •KK)
      IF (KK) 61, 60, 61
61   X=TT1
      ERROR=C16KTW(1)
      LOC=61
      GO TO 9000
60   GO TO ( 520•521 ) •1TAPER
520  RET2=FDPI/DTZLC*X2/UTV2*WTDNT
      GO TO (341•343,345), IKON
341  CALL CARCOL (X2•WTDNT/TC,DTZLC,UTV2/TC,RTV2,UTL2/TC,RTL2,
      1 ZKTL2/TC,CPTL2,HT2,SMW2)
      GO TO 599
343  CALL LMCOND (X2•WTDNT/TC,AFUDGE,ZKTL2,DTZLC,UTV2/TC,UTL2/TC,
      1 RTV2,RTL2,CPTL2,HT2,SMW2)
      GO TO 599
345  CALL ALMCON (X2•WTDNT/TC,AFUDGE,ZKTL2,DTZLC,UTV2/TC,UTL2/TC,
      1 RTV2,RTL2,CPTL2,HT2,SMW2)
599  IF (ISCHRJ) 352,62,352
352  TVAP = TT2 + 460.
      HSCHRJ = 30000. * SIGMA/ (2.0 - SIGMA) * PINTS * ZMOL **1.5 *
      1ZAMBDA **2.0 / TVAP **2.5
      HT2 = 1.0/(1.0/HT2 + 1.0/HSCHRJ)
      GO TO 62
521  IF (ICOUNT) 522,522,523
523  GO TO (361,363,365), IKON
361  CALL CARCOL (X2•WTDNT/TC,DIX,UTV2/TC,RTV2,UTL2/TC,RTL2,ZKTL2/TC,
      1 CPTL2,HT2,SMW2)
      GO TO 699
363  CALL LMCOND (X2•WTDNT/TC,AFUDGE,ZKTL2,DIX,UTV2/TC,UTL2/TC,
      1
      00435
      00436
      00437
      00438
      00439
      00440
      00441
      00442
      00443
      00444
      00445
      00446
      00447
      00448
      00449
      00450
      00451
      00452
      00453
      00454
      00455
      00456
      00457
      00458
      00459
      00460
      00461
      00462
      00463
      00464
      00465
      00466
      00467
      00468
      00469
      00470
      00471
      00472
      00473

```

```

1 RTV2•RTL2•CPTL2•HTX•SMW2) 00474
GO TO 699 00475
365 CALL ALMCON (X2•WTDNT/TC•AFUDGE•ZKTL2•DIX•UTV2/TC•UTL2/TC• 00476
1 RTV2•RTL2•CPTL2•HTX•SMW2) 00477
699 IF (ISCHRJ) 353,522,353 00478
353 TVAP = TT2 + 460. 00479
HSCHRJ = 30000. * SIGMA / (2.0 - SIGMA) * PINTS * ZMOL **1.5 * 00480
1 ZAMBDA **2.0 / TVAP ** 2.5 00481
HTX = 1.0 / (1.0/HTX + 1.0 / HSCHRJ) 00482
522 UIX = 1.0/(1.0/HTX + DIX/HSX/DOX + DIX /2.0/ZKTW * LOGF(DOX/DIX)) 00483
IF (ICOUNT) 524•524•525 00484
524 CDUM = WSDOT /ZNT *(CPS1+ CPS2 ) /2.0 00485
UIO = UIX 00486
DIXO = DIX 00487
CDUMD = CDUM / (DIXO * PI ) 00488
DUMP1 = GAMT * ( 2. * UIX + UIO ) *DIO/DIXO 00489
DUMP2 = 1.5 * (UIO + UIX ) /DUMP1 00490
THDUM = (TT1 + TT2 ) /2.0 00491
CONST = CDUMD * LOGF ((THDUM - TS2)/( THDUM-TS1))/SGRTF(1.0 +
1(GAMT/2.0*DIO)**2) 00492
RAD = DUMP2 **2 - 6. * CONST /DUMP1 00493
IF (RAD) 9004,526,526 00494
RAD = SQRTF(RAD) 00495
DL2 = DUMP2 - RAD 00496
IF (DL2) 9002,9014,527 00497
527 IF (ITERAT) 528,528,529 00498
529 USX = US2 00499
CPSX= CPS2 00500
ZKSX= ZKS2 00501
ICOUNT = ICOUNT + 1 00502
IF (ICOUNT - LIMIT) 531,531,9005 00503
531 IF (ABSF(1.0-DL20/DL2) -0.001, 528,528,530 00504
530 IF (ICOUNT -1) 505,532,533 00505
532 ZXO = DL20 00506
Y1 = UIX 00507
ZX1= DL2 00508
GO TO 505 00509
533 ZX2 = DL20 00510
ZX3 = DL2 00511
534 00512

```

```

Y2 = UIX
DY = Y1 - Y2
AU = DY / (ZX0 - ZX2)
BU = Y2 - AU *
ZX2
AQ = DY / (ZX1 - ZX3)
BQ = Y2 - AQ * ZX3
DL2 = (BU - BQ) / (AQ - AU)
IF (DL2) 534•534•535
      DL2 = (DL20 + ZX3) / 2.
534  ZX0 = ZX2
535  ZX1 = ZX3
      Y1 = Y2
      GO TO 505
528  ICOUNT = 0
      VV = PI / 12. * DL2 * ((DIXO * SMW1) ** 2 + DIXO * DIX * SMW1 *
      X  SMW2 + (DIX * SMW2) ** 2)
      VTUBE = PI / 12. * DL2 * (DIXO ** 2 + DIXO * DIX + DIX ** 2 )
      VL = VTUBE - VV
      DOTB = (DETPC1 + DETX) / 2.0 + TW / 6.0
      DSUDB = (DESPC1 + DESX) / 2.0
      RESDP2 = (RESPC1 + RESX) / 2.0
      ASFL0 = PID4 * ZNT * DOTB * DSUDB
      SUDOXB = (SUDOXB + SUDOXB1) / 2.
      BXB = ZNT * (DOTB / SUDOXB) ** 2.
      PODB = SQRTF (PI / 3.464 / BXB)
      DSB = PODB * (2.0 * ZNRO - 1.0) * DOTB
      DSQDP = DSUDB * ZNT * DOTB / (ZNT * DOTB + DSB)
      CALL TWOOPH(X1,X2,UTV1/TC•RTV1•UTL1/TC•RTL1•DETPC1*12••DIX*12••)
      1WTDOT/TC•DL2•ZNT,PINTS*144••SUMDPS•FRIC)
      GO TO 537
62   TWR=DO/ZKTW*LOGF(DODT)/2.0
      U1INV=DODT/HT1+TWR+1•0/HS1
      U2INV=DODT/HT2+TWR+1•0/HS2
      DUMP1=(TT1-TS2)/U1INV
      DUMP2=(TT1-TS1)/U2INV
      PHI2=(DUMP1-DUMP2)/LOGF(DUMP1/DUMP2)
      DL2=ZAMBDA/P1*WTDOT/DO*DX/PHI2
      DL2=DL2/ZNT
      VV=PI/12.0*DL2*DTZLC**2*(SMW1**2+SMW1*SMW2+SMW2**2)

```

```

VCYL = PID4 * DTZLC ** 2 * DL2
VL=VCYL-VV
RESDP2 = (RES1 + RES2)/2.0
ASTOT = PID4 * ZNT * DO * DO /B
ASFLO = :ASTOT * (1.0 -B)
DSQDP = FDPI * ASFLO / (DS + ZNT * DO )
U2 = 1.0/U2INV
CALL TWOPH(X1,X2,UTV1/TC,RTV1,UTL1/TC,RTL1,DT,DT,WTDOT/TC,DL2,
IZNT,PINTS*144.*SUMDPS,FRIC),
537 WTV=VV*(RTV1+RTV2)/2.0
WTL=VL*(RTL1+RTL2)/2.0
WTTOT=WTV+WTL
WME=WME+WTTOT
SLTCON=SLTCON+DL2
FRIC = FRIC/144.
DPTSTA = SUMDPS/144.
PINTS = PINTS - DPTSTA
SDPSTA = SDPSTA + DPSTA
CALL UNBAR (C1ORS •1,TS1 ,•O•O,RS1 •KK)
IF (KK) 63,64,63
X=TS1
ERROR=C1ORS (1)
LOC=63
GO TO 9000
64 CALL UNBAR (C1ORS •1,TS2 ,•O•O,RS2 •KK)
IF (KK) 156,157,156
156 X=TS2
ERROR=C1ORS (1)
LOC=156
GO TO 9000
157 RS2BAR=(RS1+RS2)/2.0
IF (RESDP2 - 2300.) 560,560,561
560 FFSDP = 64./RESDP2
GO TO 562
561 FFSDP = •316/RESDP2 **•25
562 DPS2 = FFSDP*DL2/DSQDP/144.0 *(WSDOT/ASFLO)**2.0/GK/RS2BAR
C THIS SHOULD TAKE CARE OF THE 100 SERIES
C

```

```

SDPS1N=SDPS1N+DPS2
GO TO (151•152) •1TAPER
152 IF (1) 153•153•154
153 WRITE OUTPUT TAPE NN• 5005
GSOUT = GSOUTS
ZDIO = DIO * 12•
ZDS = DS * 12•
WRITE OUTPUT TAPE NN• 5000• X1•TT1•TS1•ZDIO•ZDS•B•POD•ZNUS1
SAVBK(1)=X1
SAVBK(2)=HT1
SAVBK(3)=HS1
SAVBK(4)=UIO
SAVBK(5)=RET1
SAVBK(6)=RESPC1
SAVBK(7)=PINTZ
IS = 0
I = 1
154 X1 = X2
DIX = DIO * (1•0 - GAMT * SLTCON)
SUDOX = DSO * (1•0 - GAMS * SLTCON)
BX = (DIX + TW/6•0)**2•* ZNT / SUDOX **2•
PODX = SQRTF( PI /3•464 / BX)
RETX = FDPI * X2 / DIX * WTDNT / UTV2
DSX = PODX * (2•0 * ZNRO - 1•0) * (DIX + TW / 6•0)
TS1 = TS2
ZDIX = DIX * 12•
ZDSX = DSX * 12•
ZDL2 = DL2 * 12•
WRITE OUTPUT TAPE NN•5001•X2•TT2•TS2•ZDIX•ZDSX•BX•PODX•ZDL2•ZNUSX
IS = IS+8
SAVBK( IS )=X2
SAVBK( IS+1 )=HTX
SAVBK( IS+2 )=HSX
SAVBK( IS+3 )=UIX
SAVBK( IS+4 )=RETX
SAVBK( IS+5 )=RESX
SAVBK( IS+6 )=PINTS
SAVBK( IS+7 )=FRIC
GO TO 17C3
00591
00592
00593
00594
00595
00596
00597
00598
00599
00600
00601
00602
00603
00604
00605
00606
00607
00608
00609
00610
00611
00612
00613
00614
00615
00616
00617
00618
00619
00620
00621
00622
00623
00624
00625
00626
00627
00628
00629

```

```

151  IF(I)65,65,66
65  WRITE OUTPUT TAPE NN. 650
U1 = 1.0/U1INV
WRITE OUTPUT TAPE NN. 660.X1.TT1.PINTZ,HT1.HS1.U1
IS=1
SAVBK((IS)) =X1
SAVBK((IS+1))=ZNUS1
SAVBK((IS+2))=RET1
SAVBK((IS+3))=RES1
I=1
X1=X2
66  ZDL2= DL2 * 12 *
      WRITE OUTPUT TAPE NN. 661.X2.TT2.ZDL2,PINTS,HT2.HS2.U2
SAVBK((IS+4))= X2
SAVBK((IS+5))=ZNUS2
SAVBK((IS+6))=RET2
SAVBK((IS+7))=RES2
SAVBK((IS+8))=DPTSTA
SAVBK((IS+9))=FRIC
IS = IS + 6
TS1=TS2
1703 CALL UNBAR (C13PIN,1,PINTS,0.0,TT1,KK)
IF(KK) 1704,1705,1704
1704 X = PINTS
ERROR = C13PIN(1)
LOC = 1704
GO TO 9020
1705 TT2 = TT1
CALL UNBAR (C14ZAM,1,TT1,0.0,ZAMBDA,KK)
IF (KK) 1706,118, 1706
1706 X = TT1
ERROR = C14ZAM(1)
LOC = 1706
GO TO 9000
C   START OF 200 SERIES.
C
119 WRITE OUTPUT TAPE NN. 5006
GO TO (918,919),ITAPER

```

```

00669
00670
00671
00672
00673
00674
00675
00676
00677
00678
00679
00680
00681
00682
00683
00684
00685
00686
00687
00688
00689
00690
00691
00692
00693
00694
00695
00696
00697
00698
00699
00700
00701
00702
00703
00704
00705
00706
00707

918 WRITE OUTPUT TAPE NN, 662, (SAVBK(I),I=1,4)
IS = IS + 3
00669
00670
00671
00672
00673
00674
00675
00676
00677
00678
00679
00680
00681
00682
00683
00684
00685
00686
00687
00688
00689
00690
00691
00692
00693
00694
00695
00696
00697
00698
00699
00700
00701
00702
00703
00704
00705
00706
00707

919 WRITE OUTPUT TAPE NN, 5002, (SAVBK(I),I=1,7)
IS = IS+7
00669
00670
00671
00672
00673
00674
00675
00676
00677
00678
00679
00680
00681
00682
00683
00684
00685
00686
00687
00688
00689
00690
00691
00692
00693
00694
00695
00696
00697
00698
00699
00700
00701
00702
00703
00704
00705
00706
00707

917 AOUT = PID4 * DEXIT **2
DEXIT = DIX
REMVX2= WTDNT * FDPI / DEXIT
IF (XOUTT) 460,460,461
00669
00670
00671
00672
00673
00674
00675
00676
00677
00678
00679
00680
00681
00682
00683
00684
00685
00686
00687
00688
00689
00690
00691
00692
00693
00694
00695
00696
00697
00698
00699
00700
00701
00702
00703
00704
00705
00706
00707

461 RELOUT = REMVX2 * (1.0 - XOUTT) / UTV2
REGOUT = REMVX2 * (XOUTT) / UTV2
IF (RELOUT - 1000.) 462,463,463
462 IF (REGOUT - 1000.) 464,465,465
463 IF (REGOUT - 1000.) 466,467,467
464 CXOUT = (RELOUT/REGOUT*RTV2/RTL2)**.5*UTL2/UTV2
GO TO 468
465 CXOUT = (347.826*RTV2/RTL2)**.5*(UTL2/UTV2)*RELOUT**.5/REGOUT**.9
GO TO 468
466 CXOUT = (.002875*RTV2/RTL2)**.5*(UTL2/UTV2)*RELOUT**.9/REGOUT**.5
GO TO 468
467 CXOUT = UTL2/UTV2*(RELOUT/REGOUT)**.9*(RTV2/RTL2)**.5
468 XPO = .299 * CXOUT.** .756
RLOUT = XPO / (1.0 + XPO)
RГОUT = 1.0 - RLOUT
DUMPM1 = (1.0 - XOUTT)**2 /(RTL2 * RLOUT * AOUT)
DUMPM2 = XOUTT **2 /(RTV2 * RGOUT * AOUT)
GO TO 469
469 DUMPM1 = 0.0
DUMPM2 = 0.0
DUMPM3 = (1.0 - XINT)**2 /(DNSLIN * RLIN * AINT)
DUMPM4 = XINT**2 /(DNSVIN * RGIN * AINT)
DELQ = WTDNT **2 /GK *(DUMPM1 + DUMPM2 - DUMPM3 - DUMPM4) *
1 2.0 / (AINT + AOUT) /144.
SDPTOT = SDPSTA - DELQ
GO TO (1917.999)*IFRITZ
1917 TSN = TS2

```

```

SDPSNM= 0.0          00708
SDPTNM=0.0.C         00709
SLTSUB=0.0.0          00710
STUMP = 0.0           00711
ICOUNT = 0            00712
IF (ITAPER -1 ) 542.542. 38   00713
DINO = DIO * ( 1.0 - GAMT * SLTCN )
SDONO = DSO*(1.0 - GAMS*SLTCN)
RETNO = FDPI * WTDNT/DINO/UTLN
DSNX = PODX * ( 2.0 * ZNRO - 1.0 ) * DOX
DSNOX = DSNX          00718
GO TO 1539          00719
RETNO = FDPI * WTDNT/DTZLC/UTLN
DSNX = DS             00720
00721
1539 TTN = TTI        00722
IF (TTN - TOUTT) 9010.9012.539 00723
539 K=0               00724
I=0
IF (M) 701.701.702  00725
M = 1                00726
00727
702 DTT =(TTN-TOUTT)/FLOATF(M) 00728
00729
30 K=K+1              00729
IF (M-K) 114.113.113 00730
TTN1=TTN-DTT          00731
CALL UNBAR (C9CPS .1.TSN .0.0.CPSN .KK)
IF (KK) 71.72.71      00732
00733
71 X=TSN               00734
ERROR=C9CPS (1)
LOC=71                00735
00736
GO TO 9000             00737
CALL UNBAR (C5CP TL.1.TTN .0.0.CPTLN .KK)
IF (KK) 73.74.73      00738
X=TTN                00739
00740
73 ERROR=C5CP TL (1)  00741
LOC=73                00742
GO TO 9000             00743
00744
74 TSN1=TSN-WTDOT/WSDOT*CPTLN/CPSN*(TTN-TTN1)
CALL UNBAR (C11US .1.TSN .0.0.USN. .KK)
IF (KK) 75.1376.75    00745
00746

```

```

1376 IF (TTN - TSN) 9017,9018,1377      00747
1377 IF (TTN1 - TSN1) 9017,9018,76      00748
75 X=TSN      00749
          ERROR=C11US (1)
LOC=75      00750
GO TO 9000  00751
CALL UNBAR (C11US .1,TSN1 ,0..0,USN1 ,KK)
IF (KK)77,78,77  00752
76 X=TSN1    00753
          ERROR=C11US (1)
LOC=77      00754
GO TO 9000  00755
CALL UNBAR (C7UTL .1,TTN ,0..0,UTLN ,KK)
IF (KK)79,80,79  00756
77          LOC=77      00757
          ERROR=C11US (1)
LOC=77      00758
GO TO 9000  00759
CALL UNBAR (C7UTL .1,TTN ,0..0,UTLN ,KK)
IF (KK)79,80,79  00760
78          LOC=77      00761
          ERROR=C7UTL (1)
LOC=79      00762
GO TO 9000  00763
CALL UNBAR (C7UTL .1,TTN1 ,0..0,UTLN1 ,KK)
IF (KK)81,82,81  00764
79 X=TTN     00765
          LOC=79      00766
          ERROR=C7UTL (1)
LOC=79      00767
GO TO 9000  00768
CALL UNBAR (C7UTL .1,TTN1 ,0..0,UTLN1 ,KK)
IF (KK)81,82,81  00769
80 X=TTN1    00770
          LOC=81      00771
          ERROR=C7UTL (1)
LOC=81      00772
GO TO 9000  00773
GO TO (540,604),1 TAPER
604 DLN1 = 0..0
UTLNX = UTLN
USNX = USN
DLN10 = DLN1
541 DINX = D10 *(1.-GAMT*(SLTCON + SLTSUB + DLN1))
SUDONX = DSO *(1.-GAMS *(SLTCON + SLTSUB + DLN1))
DONX = DINX + TW/6..0
BNX = ZNT *(DONX/SUDONX)**2.
GSNX = FDPI/ZNT*MSDOT/DONX**2.*BNX/(1..0-BNX)
GTNX = WTDNT * FDPI/DINX/DINX
IF (DINX - DIMIN/12..0) 753,753,754
753 GAMT = .5 * GAMT
KILL = 1
          ERROR = 1..0

```

```
LOC = 200          00786
754  IF (BNX - BMAX) 756,756,755 00787
755  GAMS = .5 * GAMS 00788
      KILL = 1 00789
      ERROR = ERROR + 2.0 00790
      LOC = 200 00791
      IF (KILL) 758,758,9100 00792
      DESNX =(SUDONX **2.0-ZNT*DONX **2.0)/ZNT/DONX 00793
      758  PODNX = SQRTF(PI/3.464/BNX) 00794
      DETNX = DINX 00795
      RESNX = DESNX * GSNX / USNX 00796
      RETNX = DETNX * GTNX / UTLNX 00797
      DSNX = PODNX * (2.0 * ZNRO - 1.0) *DONX 00798
      IF (1 COUNT) 641,641,759 00799
      540  RESN = DE * GS/USN 00800
      RESN1 = DE* GS/USN1 00801
      RETN = DTZLC * GT/UTLN 00802
      RETN1 = DTZLC * GT/UTLN1 00803
      CALL UNBAR (C12KS .1,TSN ,0.0,ZKSN ,KK) 00804
      IF (KK) 83,84,83 00805
      X=TSN 00806
      83  ERROR=C12KS (1) 00807
```

```

LOC=83
GO TO 9000
CALL UNBAR (C12KS ,1,TSN1 ,0..0,ZKSN1 ,KK)
IF(KK)85,86,85
X=TSN1
ERROR=C12KS (1)
LOC=85
GO TO 9000
CALL UNBAR (C9CPS ,1,TSN1 ,0..0,CPSN1 ,KK)
IF(KK)91,92,91
X=TSN1
ERROR=C9CPS (1)
LOC=91
GO TO 9000
CALL UNBAR (C8KTL ,1,TTN ,0..0,ZKTLN ,KK)
IF(KK)87,88,87
X=TTN
ERROR=C8KTL (1)
LOC=87
GO TO 9000
CALL UNBAR (C5CPTL,1,TTN ,0..0,CPTLN ,KK)
IF(KK)93,94,93
X=TTN
ERROR=C5CPTL(1)
LOC=93
GO TO 9000
CALL UNBAR (C8KTL ,1,TTN1 ,C..0,ZKTLN1 ,KK)
IF(KK)89,90,89
X=TTN1
ERROR=C8KTL (1)
LOC=89
GO TO 9000
CALL UNBAR (C5CPTL,1,TTN1 ,0..0,CPTLN1 ,KK)
IF(KK)95,96,95
X=TTN1
ERROR=C5CPTL(1)
LOC=95
GO TO 9000
IF(ITAPER-1)761,761,762
PRSN = CPSN/ZKSN * USN
PRTN = CPTLN/ZKTLN * UTLN
PRSN1 = CPSN1/ZKSN1 * USN1
PRTN1 = CPTLN1/ZKTLN1 * UTLN1
IF (RETIN - 2300.)763,763,764

```

```

00852
00853
00854
00855
00856
00857
00858
00859
00860
00861
00862
00863
00864
00865
00866
00867
00868
00869
00870
00871
00872
00873
00874
00875
00876
00877
00878
00879
00880
00881
00882
00883
00884
00885
00886
00887
00888
00889
00890
00891
00892
00893
00894

763   ZNUTN = 4.36
      GO TO 765
764   ZNUTN = 7.0 + .025 * (RETN * PRTN)***.E
      CALL SHELLS (RESN,FRSN,POD,ZNSN,C19RES,KK)
      IF (KK) 1760,1761,1760
1760   X = RESN
      ERROR = C19RES(1)
      LOC = 1760
      WRITE OUTPUT TAPE NN, 9001,X,ERROR,KK,LOC
1761   HSN = ZNUSN/DE * ZKSN
      HTN = ZNUTN/DTZLC * ZKTLN
769   IF (RETN1 - 2500.) 766,766,767
766   ZNUTN1 = 4.36
      GO TO 768
767   ZNUTN1 = 7.0 + .025 * (RETN1 * PRTN1)***.E
      CALL SHELLS (RESN1,PRSN1,POD,ZNSN1,C19RES,KK)
      IF (KK) 1762,1763,1762
1762   X = RESN1
      ERROR = C19RES(1)
      LOC = 1762
      WRITE OUTPUT TAPE NN, 9001,X,ERROR,KK,LOC
1763   HSN1 = ZNUSN1/DE * ZKSN1
      HTN1 = ZNUTN1/DTZLC * ZKTLN1
      GO TO 197
762   SUDON = SUDONX
      RETNP = RETNX
      RESNP = RESNX
      DETNN = DETNX
      CPTLNX = CPTLN
      ZKTLNX = ZKTLN
      ZKSNX = ZKSN
      CPSNX = CPSN
      PODNS = PODNX
      BNS = BNX
      GO TO 760
759   ZKSNX = ZKSN1
      ZKTLNX = ZKTLN1
      CPSNX = CPSN1
      CPTLNX = CPTLN1
      USNX = USN1
      UTLNX = UTLN1
      PRSNX = USNX * CPTLNX/ZKSNX
      CALL SHELLS (RESN,FRSN,POD,ZNSN,C19RES,KK)

```

```

1764 IF (KK) 1764•1765•1764
      X = RESNX
      ERROR = C19RES(1)
      LOC = 1764

1765 WRITE OUTPUT TAPE NN, 9001!X•ERROR•KK•LOC
      HSNX = ZNUSNX * ZKSNX/DESNX
      PRTNX = UTLNX * CPTLNX / ZKTLNX
      IF (RETNX - 2300•) 770•770•771
      ZNUTNX = 4•36
      GO TO 772
      ZNUTNX = 7•0 + •025 * (RETNX * PRTNX)**•8
      HTNX = ZNUTNX / DETNX * ZKTLNX
      IF (ICOUNT) 773•773•197
      73 ZNUTNS = ZNUTNX
      ZNUSNS = ZNUSNX
      HTNS = HTNX
      HSNS = HSNX
      RESNS = RESNX
      CALL UNBAR (C16KTW•1•TTN ,0•0•ZKTW •KK)
      IF (KK) 97•601•97
      X=TTN
      ERROR=C16KTW(1)
      LOC=97
      GO TO 9000
      GO TO (98•851)•1TAPER
      851 UINX = 1•0/(1•HTNX +DETDX/HSNX/DONX +DETNX/2•ZKTW*LOGF(
      1 DONX/DETDX)

      IF (ICOUNT) 852•852•853
      852 CDUMNS = WSDOT/ZNT * (CPSN +CPSN1)/2•0
      CDUMNT = WTDNT *(CPTLN + CPTLN1)/2•0
      UINO = UINX
      DIXNO = DINX
      CDUMDN = CDUMNS/(DIXNO * P1)
      DUMP1N = (2•0 * UINX + UINO) * GAMT * DIO/DIXNO
      DUMP2N = 1•5 * (UINO + UINX)/DUMP1N
      CRAT = CDUMNS/CDUMNT
      GUNK = (TTN -CRAT*TSN -(1•-CRAT)*TSN1)/(TTN -TSN )
      CONSTN = CDUMDN * LOGF(GUNK) /(1•-CRAT)/SQRTF(1•0+(GAMT/2•0*DI
      10)*2)
      RADN = DUMP2N **2• -6•0 * CONSTN/DUMP1N
      IF (RADN) 9009•854•854
      RADN = SQRTF(RADN)
      DLN1 = DUMP2N - RADN

```

```

00938
00939
00940
00941
00942
00943
00944
00945
00946
00947
00948
00949
00950
00951
00952
00953
00954
00955
00956
00957
00958
00959
00960
00961
00962
00963
00964
00965
00966
00967
00968
00969
00970
00971
00972
00973
00974
00975
00976
00977
00978
00979
00980

IF (DLN1) 9008,1856,855
IF (ITRATN) 857,857,1655
IF (STUMP) 9007,9007,857
855 ICOUNT = ICOUNT + 1
IF (ICOUNT - LIMITN) 856,856,9006
IF(ABSF(1.0 - DLN10 /DLN1) - .001) 857,857,858
56 IF (ICOUNT -1) 541,859,860
58 ZXON = DLN10
59 Y1N = UINX
ZX1N = DLN1
GO TO 541
60 ZX2N = DLN10
ZX3N = DLN1
Y2N = UINX
DYN = Y1N - Y2N
AUN = DYN /(ZXON - ZX2N)
BUN = Y2N - AUN * ZX2N
AQN = DYN / (ZX1N - ZX3N)
BQN = Y2N - AQN * ZX3N
DLN1 = (BUN - BQN) / (AQN - AUN)
IF (DLN1) 861,861,862
DLN1 = (DLN10 + ZX3N) /2.
ZXON = ZX2N
ZX1N = ZX3N
Y1N = Y2N
GO TO 541
ICOUNT = 0
SLTSUB = SLTSUB + DLN1
RESDPN = (RESNP + RESNX) /2.
RETDPN = (RETNP + RETNX) / 2.
IF (RESDPN - 2300.) 863,863,864
FFSDPN = .316 / RESDPN **.25
GO TO 865
FFSDPN = 64. / RESDPN
IF (RETDPN - 2300.) 866,866,867
FFTDPN = 64./ RETDPN
GO TO 606
FFTDPN = .316 / RETDPN ** .25
GO TO 606
TWR=D0/ZKTW*LOGF((DODT)/2.0
UNINV=DODT/HTN+TWR+1.0/HSN
UN1INV=DODT/HTN1+TWR+1.0/HSN1
UN1 = 1.0/UN1 INV

```

```

DUMP1=(TTN1-TSN1)/UNINV
DUMP2=(TTN-TSN)/UNINV
PHIN1=(DUMP1-DUMP2)/LOGF(DUMP1/DUMP2)
DLN1=WTDOT/PHIN1*(TTN-TTN1)/PI*CPTLN /DO
DLN1=DLN1/ZNT
SLTSUB=SLTSUB+DLN1
RESDPN =(RESN+RESN1)*.5
CALL UNBAR (C10RS ,1,TSN ,0.0,RSN ,•KK)
IF (KK)99,100,99
X=TSN
99    ERROR=C10RS (1)
LOC=99
GO TO 9000
100   CALL UNBAR (C10RS ,1,TSN1 ,0.0,RSN1 ,•KK)
IF (KK)101,102,101
X=TSN1
101   ERROR=C10RS (1)
LOC=101
GO TO 9000
RSNBAR =(RSN+RSN1)/2.0
CALL UNBAR (C6RTL ,1,TTN ,0.0,RTLN ,•KK)
IF (KK)103,104,103
X=TTN
103   ERROR=C6RTL (1)
LOC=103
GO TO 9000
CALL UNBAR (C6RTL ,1,TTN1 ,0.0,RTLN1 ,•KK)
IF (KK)105,106,105
X=TTN1
104   ERROR=C6RTL (1)
LOC=105
GO TO 9000
RTLN1B=(RTLN+RTLN1)/2.0
GO TO(1610,630),ITAPER
630   SUDONB = ( SUDON + SUDONX ) / 2.0
DETNB = ( DETNN + DETNX ) / 2.0
DOTNB = DETNB + TW/6.0
BXNB = DOTNB ** 2.0 * ZNT /SUDONB ** 2.0
PODXNB = SQRTF (P1 /3.464 /BXNB)
DSNB = PODXNB * (2.0 * ZNRO - 1.0) * DOTNB
ASFLO = PID4 * ( SUDONB ** 2.0 - ZNT * DOTNB ** 2.0 )
DESNDP = FDPI * ASFLON / (DSNB + ZNT * DOTNB)
GTNB = WTDNT * FDPI / DETNB ** 2.0

```

```

DPSN1 = FFSDPN * DLN1 / DESNDP / 144.0 * (WSDOT / ASFLON) ** 2.0 / GK / RSNBAR 01024
DPTN1 = FFTDPN * DLN1 / DETNB / 144.0 * GTNB ** 2.0 / GK / RTLN1B 01025
SDPSNM = SDPSNM + DPSN1
SDPTNM = SDPTNM + DPTN1
IF (1) 1108,1108,1109
  IF (XOUTT) 1208,1208,224
    1108 WRITE OUTPUT TAPE NN, 652
    ZDETNN = DETNN * 12.
    ZDSNOX = DSNOX * 12.
    WRITE OUTPUT TAPE NN, 663,TTN,ZDETNN,ZDSNOX,BNS,PODNS
    IS2=1
    SVBK(1$2) = TIN
    SVBK(1$2+1)=HTNS
    SVBK(1$2+2)=HSNS
    SVBK(1$2+3)=UINO
    SVBK(1$2+4)=ZNUTNS
    SVBK(1$2+5)=ZNUSNS
    SVBK(1$2+6)=RETNO
    SVBK(1$2+7)=RESNS
    RHOLIN = RTLN
    RETNS = RETNP
    I = 1
  1109 TIN = ITN!
    DINX = DIOX (I. - GAMT * (SLTCQN + SLTSUB))
    SUDONX = DSO * (1. - GAMS * (SLTCQN + SLTSUB))
    BNX = ZNT * ((DINX + TW/6.0) / SUDONX) ** 2.0
    PODNX = SQRTF (PI / 3.464 / BNX)
    DSNX = PODNX * ( 2.0 * ZNRO - 1.0 ) * IDINX + TW/6.0
    IDINX = DINX * 12.
    ZDSNX = DSNX * 12.
    ZDLN1 = DLN1 * 12.
    WRITE OUTPUT TAPE NN, 661,TTN1,TSN1,ZDINX,ZDSNX,BNX,PODNX,ZDLN1,DP
    ITN1
    SVBK(1$2+8)=TTN1
    SVBK(1$2+9)=HTNX
    SVBK(1$2+10)=HSNX
    SVBK(1$2+11)=UINX
    SVBK(1$2+12)=ZNUTNX
    SVBK(1$2+13)=ZNUSNX
    SVBK(1$2+14)=RETNX
    SVBK(1$2+15)=RESNX
    IS2 = IS2 + 8
    TSN1 = TSN1
  
```

```

GO TO 30
1610 RESDPN = (RESN + RESN1)/2.0
      RETDPN = (RETN + RETN1)/2.0
      IF (RESDPN - 2300.) 1611,1611,1612
1611 FFSDPN = 64./ RESDPN
      GO TO 1613
1612 FFTDPN = .316/RESDPN **.25
1613 IF (RETDPN - 2300.) 1614,1614,1615
1614 FFTDPN = 64./RETDPN
      GO TO 1616
1615 FFTDPN = .316 / RETDPN **.25
1616 DPSN1 = FFSDPN *DLN1/DSQDP/144.* (WSDOT/ASFLO)**2./GK/RSNBAR
      DPTN1 = FFTDPN* DLN1/DTZLC/144. * GT * GT /GK / RTLN1B
      SDPSNM = SDPSNM + DPSN1
1107 SDPTNM=SDPTNM+DPTN1
      IF (I) 108,108,109
108 IF (XOUTT) 208,208,225
208 WRITE OUTPUT TAPE NN, 5015
UN = 1.0/UNINV
WRITE OUTPUT TAPE NN, 5017,TTN,TSN,HTN,HSN,UN
SAVBK(1)=TTN
SAVBK(2)=ZNUTN
SAVBK(3)=ZNUSN
SAVBK(4)=RETN
SAVBK(5)=RESN
IS = 0
RHOLIN=RTLN
RETNS=RETN
I=1
109 TTN=TTN1
      ZDLN1 = DLN1 * 12.
      WRITE OUTPUT TAPE NN, 5018,TTN1,TSN1,ZDLN1,HTN1,HSN1,UN1
      IS = IS + 6
      SAVBK (IS ) = TTN1
      SAVBK (IS+1) = ZNUTN1
      SAVBK (IS+2) = ZNUSN1
      SAVBK (IS+3) = RETN1
      SAVBK (IS+4) = RESN1
      SAVBK (IS+5) = DPTN1
      TSN=TSN1
      GO TO 30

```

C END OF 200 SERIES.

```

C 114  TOTAL = SLTCON + SLTSUB
      TINS = TSN1
      GO TO (914,915),1 TAPER
      WRITE OUTPUT TAPE NN,5016
      WRITE OUTPUT TAPE NN,5019, (SAVBK(I),I=1,5)
      IS = IS + 5
      WRITE OUTPUT TAPE NN,5018, (SAVBK(I),I=6,IS)
      GO TO 125
      915  WRITE OUTPUT TAPE NN,653
      WRITE OUTPUT TAPE NN,661, (SAVBK(I),I=1,8)
      IS2 = IS2 + 7
      WRITE OUTPUT TAPE NN,661, (SAVBK(I),I=9,IS2)
      124  RETN1 = RETNX
            GTE = GTNX
            BMTWE = BNX * (DINX/DONX)**2
            GSIN = GSX
            DEXT = DINX
            SHELEX = SUDONX
      125  GO TO (1125,999),1 FRITZ
      224  GTE = WTDNT * FDP1 / DIX **2
            BMTWE = BX * ( DIX / DOX ) **2
            GSIN = GSX
            DEXT = DIX
            SHELEX = SUDON
      225  GO TO (2125,999),1 FRITZ
      2125  X = TT2
            CALL UNBAR (C3UTV,1,TT2,0,0,UTV,KK)
      126  IF (KK) 126,127,126
            ERROR = C3UTV (1)
            LOC = 126
            GO TO 9000
            CALL UNBAR (C2RTV,1,TT2,0,0,RTV,KK)
      127  IF (KK) 128,129,128
            ERROR = C2RTV (1)
            LOC = 128
            GO TO 9000
      129  RETN1 = GTE * DEXT / UTV * XOUTT
            FUMP = XOUTT**2/GK * GTE **2
            CALL UNBAR (C6RTL,1,TT2,0,0,RTL,M,KK)
            IF (KK) 237,136,237
            X = TT2
            ERROR = C6RTL (1)

```

```

LOC = 237
GO TO 9000
1125 FUMP = GTE**2 / GK
122 CALL UNBAR (C6RTL,1,TOUTT,0.0,RTLM,KK)
IF (KK) 137,138,137
137 X=TOUTT
ERROR=C6RTL (1)
LOC=137
GO TO 9000
RETDAM = RETN1
IF (RETN1 -1000.) 139,143,140
139 WRITE OUTPUT TAPE NN, 172, RETN1
RETDAM = 1000.
GO TO 143
140 IF (RETN1-1.E8) 143,143,144
143 ZKE = -LOGF(BMTWE)/1.959 + LOGF(RETDAM)/159.--.205
GO TO 145
144 ZKE = -LOGF(BMTWE)/1.959 - .0891
145 IF (XOUTT) 1145,1145,2145
145 .DPTEXT = FUMP /RTLM * (ZKE) /144.
GO TO 3145
2145 DPTEXT = FUMP/RTV * ZKE /144.
3145 SPTTOT = PTENTT + SDPTOT + DPTEXT + SDPTNM
CALL UNBAR (C1ORS ,1,TINS ,0.0,RSM ,KK)
IF (KK) 146,147,146
146 X=TINS
ERROR=C1ORS (1)
LOC=146
GO TO 9000
147 CALL UNBAR (C1ORS ,1,TOUTS ,0.0,RS1 ,KK)
IF (KK) 148,149,148
148 X=TOUTS
ERROR=C1ORS (1)
LOC=148
GO TO 9000
RS1MB=(RS1+RSM)/2.0
VS1 = GSIN/RSM/TC
VS2 = GSOUT/RS1/TC
DPSIN = ALPHA1 * RSM * VS1 * VS2 / G / 288.
DPSOUT = ALPHA2 * RS1 * VS2 * VS1 * VS2 / G / 288.
ZMT = RTW*PI*ZNT*TOTLT*TW/ 24.* (DTZLC +DEXT+ TW/6.)
ZMS = RSW*PI*TOTLT*TS/24.* (TS/6.0 + DS + DSNX)
DUMP=ZNT*PI*2*(1.0-E)/B

```

```

ZMTS = RTS*TT$/ 12.*PID4* (DSUDO**2 + SHELEX**2 - ZNT*( DTZLC**2 +
1DEXT**2) ) 01196
ZMSF = RS1MB* TOTLT* P1/12.* (DSUDO* SHELEX +DSUDO**2 + SHELEX**2 01197
1-ZNT* (DO* ( DO + (DEXT + TW/6.) ) + (DEXT +TW/6.)***2) ) 01198
ZMTF = PID4.* (DETNN*DEXT) /3. *ZNT * SLTSUB* 01199
ZMTL = DETNN*DEXT*2 + DEXT*2 + 01200
ZRTLM +WME*ZNT 01201
ZMTOT=ZMT+ZMS+ZMTS+ZMSF+ZMTF 01202
DPSTOT = DPSIN + SDPSIN + SDPSNM + DPSOUT 01203
999 ZDO = DO * 12. 01204
ZDE = DE * 12. 01205
ZDS = DS * 12. 01206
ZTOTLT = TOTLT * 12. 01207
ZLTCON = SLTCON * 12. 01208
ZLTSUB = SLTSUB * 12. 01209
WRITE OUTPUT TAPE NN, 69, (ANS(I), I=1,27) 01210
VT=VTSAVE 01211
PINT = PINSAV 01212
TINT = TINSAV 01213
WRITE OUTPUT TAPE NN, 165 01214
GO TO 1 01215
1000 CONTINUE 01216
RETURN 01217
2000 WRITE OUTPUT TAPE NN, 90Q1,X,ERROR,KK,LOC 01218
3001 FORMAT (21H0 CURVE OUT OF RANGE.. 3H X=E20.9.11H ERROR NO.=F5.0. 01219
15H KK=12.6H LOC=14) 01220
GO TO 999 01221
9002 WRITE OUTPUT TAPE NN, 9102 01222
9102 FORMAT (5BH NEGATIVE CONDENSING SECTION INCREMENTAL LENGTH CALCUL 01223
1ATED) 01224
IFRITZ = 2 01225
GO TO 119 01226
9003 WRITE OUTPUT TAPE NN, 9103 01227
9103 FORMAT (65H PROGRAM CANNOT HANDLE CASE OF TAPERED SHELL WITHOUT T 01228
1APERED TUBE) 01229
GO TO 1 01230
9004 WRITE OUTPUT TAPE NN, 9104 01231
9104 FORMAT (59H IMAGINARY CONDENSING SECTION INCREMENTAL LENGTH CALCU 01232
1LATED) 01233
IFRITZ = 2 01234
GO TO 119 01235
9005 WRITE OUTPUT TAPE NN, 9105 01236
9105 FORMAT (63H ITERATION FOR CONDENSING INCREMENTAL LENGTH FAILED TO 01237
1 CONVERGE) 01238

```

```

IFRITZ = 2
GO TO 119
9006 WRITE OUTPUT TAPE NN, 9106
9106 FORMAT (63H ITERATION FOR SUBCOOLING INCREMENTAL LENGTH FAILED TO
1 CONVERGE)
IFRITZ = 2
GO TO 114
9007 WRITE OUTPUT TAPE NN, 9107
9107 FORMAT (60H SUBCOOLING SECTION INCREMENTAL LENGTH CALCULATED TO BE
1 ZERO)
IFRITZ = 2
GO TO 114
9008 WRITE OUTPUT TAPE NN, 9108
9108 FORMAT (58H NEGATIVE SUBCOOLING SECTION INCREMENTAL LENGTH CALCULA
1 TED)
IFRITZ = 2
GO TO 114
9009 WRITE OUTPUT TAPE NN, 9109
9109 FORMAT (59H IMAGINARY SUBCOOLING SECTION INCREMENTAL LENGTH CALCUL
1ATED)
IFRITZ = 2
GO TO 114
9010 WRITE OUTPUT TAPE NN, 9011
9011 FORMAT (62H TUBE TEMPERATURE OUT OF CONDENSING SECTION IS LESS THA
1N TOUTT)
150 STUMP = 1.0
DLN1 =0.0
K = M
I = 0
DTT = 0.0
GO TO 113
9012 WRITE OUTPUT TAPE NN, 9013
9013 FORMAT (94H TUBE TEMPERATURE OUT OF CONDENSING SECTION IS EQUAL TO
1 TOUTT ! NO SUBCOOLING SECTION REQUIRED)
GO TO 150
9014 WRITE OUTPUT TAPE NN, 9114
9114 FORMAT (60H CONDENSING SECTION INCREMENTAL LENGTH CALCULATED TO B
1E ZERO)
IFRITZ = 2
GO TO 119
9015 WRITE OUTPUT TAPE NN, 9115
9115 FORMAT (67H CONDENSING SECTION TUBE TEMPERATURE IS LESS THAN SHEL
1L TEMPERATURE)

```

```

IFRITZ = 2
GO TO 119
9016 WRITE OUTPUT TAPE NN, 9116
9116 FORMAT (66H CONDENSING SECTION TUBE TEMPERATURE IS EQUAL TO SHELL
1 TEMPERATURE)
IFRITZ = 2
GO TO 119
9017 WRITE OUTPUT TAPE NN, 9117
9117 FORMAT (67H SUBCOOLING SECTION TUBE TEMPERATURE IS LESS THAN SHELL
1L TEMPERATURE)
IFRITZ = 2
GO TO 114
9018 WRITE OUTPUT TAPE NN, 9118
9118 FORMAT (66H SUBCOOLING SECTION TUBE TEMPERATURE IS EQUAL TO SHELL
1 TEMPERATURE)
IFRITZ = 2
GO TO 114
9019 WRITE OUTPUT TAPE NN, 9119
9119 FORMAT (56H PROGRAM CANNOT HANDLE CASE HAVING NO CONDENSING SECTION
1N)
GO TO 1
9020 WRITE OUTPUT TAPE NN, 9120,X,ERROR,KK,LOC
9120 FORMAT (21HO CURVE OUT OF RANGE., 3H X=E20.9,11H ERROR NO.=F5.0,
15H KK=12,6H LOC=14)
IFRITZ = 2
GO TO 119
9100 WRITE OUTPUT TAPE NN, 9101,ERROR,LOC,GAMS,GAMT,DL2,DLN1
9101 FORMAT (29H EXCESSIVE TAPER. ERROR NO. F5.2,7H LOC = 14,BH GAMS
1E.F10.7, BH GAMT = F10.7,7H DL2 = F10.7,BH DLN1 = F10.71
GO TO 999
2 FORMAT (12A6)
3 FORMAT (24I2)
6 FORMAT (5E14.5)
8 FORMAT (12,E14.5)
11 FORMAT (96HO N M KURVE=1.2.3.4.5.6.7.8.9.10.11.12.13.14.15 ICHA
1NGE IKON ISCHRJ ITERAT ITRATN LIMIT LIMIT
2/213.7X,912,613.4X,11.6X,11.4X,11.4(5X,12))
12 FORMAT (120HO WTDOT TINT
1TOUTS XINT XOUTT ALPHA1
2/1X,BE15.5/,120HO WSDOT TTS B ZNT
3 DT PINT ZNRO RTW P
4HUJ /IX,8E15.5 /120HQ RTS SIGMA
5 RSW

```

6 ZMOL /1X.8E15.5/ GAMS DIMIN /1X.3E15.5/ 01325
 744HO GAMT 01326
 67 FORMAT (1X.E13.5.13X.6E13.5) 01327
 68 FORMAT (1X.9E13.5) 01328
 69 FORMAT //120HO QD TUBE DEQ SHELL ID SHELL 01329
 1 G SHELL G TUBE V TUBE IN V SHELL IN V SHELL O 01330
 2UT//8E15.5./45HO TOT LENGTH = (CON LENGTH) + (SUB LENGTH) //3E 01331
 315.5./75HO SUM DP TUBE = (DP ENT TOT) + (DP CON TOT) + (DP SUB 01332
 4 TOT) + (DP EXT TOT) //5E15.5./75HO SUM DP SHELL = (DP SHELL IN) + 01333
 5(DP SHELL CON)+(DP SHELL SUB)+(DP SHELL OUT)//5E15.5./91HO 01334
 6TOTAL WT=(TUBE FLUID WT)+(SHL FLUID WT)+(TUBE WALL WT)+(SHL WALL W 01335
 7T)+(TUBE SHEET WT)//6E15.5) 01336
 141 FORMAT (6HORETA=E20.9.36H IS LESS THAN 1000. KC=F(RETAA=1000.)) 91337
 142 FORMAT (6HORETM=E20.9.36H IS LESS THAN 1000. KE=F(RETMM=1000.)) 01338
 165 FORMAT (1H1) 01339
 172 FORMAT (9H RETN1 = F5.2+4H WHICH IS LESS THAN 1000. SET RETDAM = 01340
 1 1000.) 01341
 5000 FORMAT (117HO QUALITY TUBE FLUID SHELL FLUID TUBE I.D. 01342
 1 SHELL I.D. BLOCKAGE P/D INCREMENTAL NU SHELL 01343
 2/19X.17HTEMP TEMP60X.6HLENGTH/1X.7E13.5.13X.E13.5) 01344
 5001 FORMAT (1X.9E13.5) 01345
 5002 FORMAT (105HO QUALITY H TUBE H SHELL OVERALL HEAT 01346
 1 RE TUBE RE SHELL STATIC INCREMENTAL/40X.24HTRANS. 01347
 2COEFF U VAPOR 19X.23HPRESSURE DP FRICTION /1X.7E13.5) 01348
 5003 FORMAT (1X.8E13.5) 01349
 5005 FORMAT (/// 51X.18HCONDENSING SECTION) 01350
 5006 FORMAT (/// 46X.27HCONDENSING SECTION (CONT'D)) 01351
 5015 FORMAT (/// 51X.18HSUBCOOLING SECTION) 01352
 5016 FORMAT (/// 46X.27HSUBCOOLING SECTION (CONT'D)) 01353
 5017 FORMAT (80HO TUBE LIQUID SHELL FLUID INCREMENTAL H TUBE 01354
 1 H SHELL OVERALL HEAT 01355
 2/ BOH TEMP LENGTH 01356
 3 TRANS COEFF / 73X.1HU /1X.2E13.5.13X.3E13.5) 01357
 5018 FORMAT (1X.6E13.5) 01358
 5019 FORMAT (80HO TUBE LIQUID NU TUBE NU SHELL RE TUBE 01359
 1 RE SHELL INCREMENTAL/10H TEMP.58X.13HDPTUBE TOTAL/1X.5E 01360
 213.5) 01361
 650 FORMAT (120HO QUALITY TUBE FLUID SHELL FLUID INCREMENTAL 01362
 1 STATIC H TUBE H SHELL OVERALL HEAT 01363
 2/ 120H TEMPERATURE TEMPERATURE LENGTH 01364
 3 PRESSURE TRANS COEFF U 01365
 4) 01366
 652 FORMAT (///50X.20H SUBCOOLING SECTION / 01367

```

1 120HO TUBE FLUID SHELL FLUID TUBE I.D. SHELL I.D. 01368
2 BLOCKAGE P/D INCREMENTAL INCREMENTAL 01369
3/ 119H TEMPERATURE TEMPERATURE 01370
4 LENGTH DP TUBE 1. 01371
653 FORMATS // /50X,31H SUBCOOLING SECTION (CONTINUED) / 01372
1 120HO TUBE FLUID H TUBE H SHELL OVERALL HEAT 01373
2 NU TUBE NU SHELL RE TUBE RE SHELL 01374
3/ 119H TEMPERATURE TRANSFER 01375
4
5 119H /
660 FORMAT (1X,3E13.5,13X,4E13.5) 01376
661 FORMAT (1X,8E13.5) 01377
662 FORMAT (82HO QUALITY NU SHELL RE TUBE RE SHELL 01378
1 INCREMENTAL INCREMENTAL /32X, 5HVAPOR,20X, 7HD P TUBE,9X,2HD P 01379
25.7X, 6HSTATIC,6X, 8HFRICTION /1X,4E13.5) 01380
663 FORMAT (1X,6E13.5)
1903 FORMAT(52H1PRATT AND WHITNEY AIRCRAFT CONDENSER DESIGN PROGRAM ) 01381
END 01382
CTWOPH 01383
SUBROUTINE TWOPH(XINA,XOUTA,UG,RG,UL,RL,DTINA,DTOUTA,WSUM,ZLTA,
1ZNSUM,PINA,SUMDPS,FRIC)
EQUIVALENCE (ANS(1),X1),(ANS(2),X2),(ANS(3),X3),(ANS(4),X4);
1,ANS(5),DPFTV),(ANS(6),QEQQTV),(ANS(7),DPSTV),(ANS(8),DPTTV),
2,(ANS(9),DPFTT),(ANS(10),QEQQTT),(ANS(11),DPSTT),(ANS(12),DPTTT),
3,(ANS(13),DPFVV),(ANS(14),QEQQVV),(ANS(15),DPSVV),(ANS(16),DPTVV),
4,(ANS(17),DPFVT),(ANS(18),QEQQVT),(ANS(19),DPSVT),(ANS(20),DPTVT)
DIMENSION NX(4), QIN(4), QOUT(4), DUMP(6), ANS(20)
1ERROR = 0
G=32.17405
NST = 1
IDPC = 0
IBOIL = 0
ZLC=12.0
NN = 2
PI=3.141592653589
IF(TQDLP)45,46,45
39 TQDLP=.01
46 IF(IDPC)67,52,67
45
67 ITER=-1
Z1=ZNSUM
ZNSUM=ZNSUM
ZBOUND=5.
01406
01407
01408
01409
01410

```

```

ZNSUM=ZBOUND
      52 PIN = PINA
      PSUM=0.0
      SUMDPF=0.0
      SUMDQ=0.0
      SUMDPT=0.0
      DO 80 ISTA=1,NST
      DO 150 I=1,20
      ANS(I)=0.0
      PIN=PIN-PSUM
      XIN=XINA
      XOUT=XOUTA
      DTIN=DTINA
      JQ=1
      DO 131 I=1,4
      NX(I)=0
      QIN(I)=0.0
      QOUT(I)=0.0
      CONTINUE
      IF (XOUT-XIN)95,93,93
      WRITE OUTPUT TAPE NN, 94, XOUT,XIN
      IERROR = 1
      GO TO40
      95 ZLT=ZLTA
      DTZLC=(DTINA
      +DTOUTA
      )/24.
      DT=DTZLC*12.
      SAVE1 = 785.0/WSUM*DTZLC
      RR=(RG/RL)**.5
      ULX125=UL**.125
      ULX5=UL**.5
      UGX125=UG**.125
      UGX5=UG**.5
      SAVE2=8.0/G*(WSUM/PI)**2
      ZK1=.228/G*UG**.25/RG*ZLT/DTZLC**4.75*WSUM**1.75
      ZK2=.13.0/UGX125*ULX5*RR*(ZNSUM/(WSUM*12.))**.375
      ZK3=RR/UGX125*ULX125
      ZK4=.41.3/G*UG/RG*ZLT/DTZLC**4*WSUM
      ZK5=.0744/UGX5*ULX125*RR*(WSUM/ZNSUM*12.))**.375
      ZK6=RR/UGX5*ULX5
      XE=XIN
      XVL=1.0-SAVE1*ZNSUM*UL
      IF (XVL-XOUT)1,2,2
      XVL=XOUT

```

```

2   XVG=SAVE 1*ZN SUM*UG
     IF(XVG-XOUT)15,29,29
      XVG=XOUT
      5   IF(XIN-XVGL)3, 3,12
      3   IF(XIN-XVG)4, 4,6
      4   XO=XOUT
          GO TO 9
      6   XO=XVG
      28  X3=(XE-XO)/(XIN-XOUT)
      97  QEQOTT=0.0
          DPSTT=0.0
          DPTTT=0.0
          DPFTT=0.0
          GO TO 25
      96  EX=.875
          NX(JQ)=3
          DUMP(1)=.533
          DUMP(2)=-.304
          DUMP(3)=-.0141
          DUMP(4)=-.0042
          DUMP(5)=-.00186
          DUMP(6)=-.00566
          DUMP7=19.7*ZK3
          DUMP8=.364*ZK3**2*((1.0-XE)**2.75-(1.0-XO)**2.75)
          DUMP9=.364*(XE**2.75-XO**2.75)
          I=1
          GO TO 2000
      7   DPETI=ZK1/(XIN-XOUT)*DPTPF/ZNSUM**1.75
          D11=ZK3
          D10=ZK3
          D2=1.339
          D3=.661
          D4=.661
          D5=1.339
          GO TO 3000
          QEQOTT=QEQQ/ZNSUM**2
      8   IF(1BQJL)116,115,116
      116  DPSTT=-DPFTT-2.0*QEQQTT
          DPTTT=-DPFTT-QEQOTT
          GO TO 25
      115  DPSTT=DPFTT-2.0*QEQQTT

```

```

01497
01498
01499
01500
01501
01502
01503
01504
01505
01506
01507
01508
01509
01510
01511
01512
01513
01514
01515
01516
01517
01518
01519
01520
01521
01522
01523
01524
01525
01526
01527
01528
01529
01530
01531
01532
01533
01534
01535
01536
01537
01538
01539

25      DPTTT=DPTTT-QEQOTT
        XE=XO
        XQ=XOUT
        X4=(XE-XO)/(XIN-XOUT)
        IF((X4)98.99.98
        QEQOTT=0.0
        DPSTV=0.0
        DPTTV=0.0
        DPFTV=0.0
        GO TO 17
        EX=.5
        NX(JQ)=4
        TEMR=ZK5/DT    **.375
        DUMP(1)=.667
        DUMP(2)=-.35
        DUMP(3)=-.01562
        DUMP(4)=-.00455
        DUMP(5)=-.000198
        DUMP(6)=-.00598
        DUMP7=11.0*TEMR
        DUMP8=.364*TEMR**2*((1.-XE)**2.75-(1.0-XO)**2.75)
        DUMP9=0.5*(XE**2-XO**2)
        I=2
        GO TO 2000
        DPFTV=ZK4/(XIN-XOUT)*DPTPF/ZNSUM
        D11=ZK5/DTINA   **.375
        D10=ZK5/DTOUTA  **.375
        D2=1.622
        D3=.661
        D4=.378
        D5=1.339
        GO TO 3000
        QEQOTT=QEQQ/ZNSUM**2
        IF((IBOIL)118.117.118
        1118 DPSTV=-DPFTV-2.0*QEQQTV
        DPFTV=-DPFTV-QEQOTT
        GO TO 17
        DPSTV=DPFTV-2.0*QEQQOTT
        DPFTV=DPFTV-QEQOTT
        C DPTPF=DPFTT+DPFTV+DPFVV+DPFVT
        C QEQQ=QEQQTT+QEQQTV+QEQQVV+QEQQVT
        C DPTPS=DPSTT+DPSTV+DPSVV+DPSVT
        C DPTPT=DPPTT+DPPTV+DPTVV+DPTVT

```

```

PSUM = CDPTPS
SUMDPF = SUMDPF+CDPTPF
IF (IDPC) 51,36,35
      J=1
      GO TO 4000
      RELE=ABSF((DPT-CDPTPT)/DPT)
      IF (IPRINT) 43,50,43
      43   WRITE OUTPUT TAPE NN,49,RELE
      J=2
      GO TO 4000
      IF (IRELE-.01) 47,47,48
      IF (ITER) 55,56,58
      55   ITER=0
      ZNSUM=ZNSUM
      IF (ABSF(CDPTPT)-ABSF(DPT)) 57,52,52
      WRITE OUTPUT TAPE NN, 63, ZBOUND,CDPTPT
      IERROR = 2
      GO TO 52
      DP1=DPT-CDPTPT
      Z2=CDPTPT/DPT*ZNSUM
      IF (Z2-ZBOUND) 59,60,60
      59   Z2=ZBOUND
      60   ZNSUM=Z2
      GO TO 44
      DP2=DPT-CDPTPT
      Z3=Z2+DP2/(DP1-DP2)*(Z2-Z1)
      IF (Z3-ZBOUND) 61,62,62
      61   Z3=ZBOUND
      62   ZNSUM=Z3
      DP1=DP2
      Z1=Z2
      Z2=Z3
      44   ITER=ITER+1
      IF (ITER-50) 52,52,53
      WRITE OUTPUT TAPE NN, 54
      IERROR = 3
      GO TO 41
      NSUM=ZNSUM
      IF (FLOATF(NSUM)-ZNSUM) 69,51,69
      69   ZNSUM=NSUM+1
      IDPC=-1
      GO TO 52
      J=3
      51

```

```

64 GO TO 4000
IDPC=1
41 GO TO 79
12 IF(XIN-XVG)13,13,18
13 XQ=XVL
27 X2=(XE-XO)/(XIN-XOUT)
IF((X2)100,101,100
101 QEQQVV=0.0
DPSVV=0.0
DPTVV=0.0
GO TO 102
100 EX=.5
NX(JQ)=2
DUMP(1)=.667
DUMP(2)=-.2
DUMP(3)=-.0357
DUMP(4)=-.0139
DUMP(5)=-.00711
DUMP(6)=-.042
DUMP7=.0*ZK6
DUMP9=.5*(XE**2-XO**2)
DUMP8=ZK6**2*((XE-XO)-DUMP9)
1=3
GO TO 2000
DPFVV=ZK4/(XIN-XOUT)*DPTPF/ZNSUM
14 D11=ZK6
D10=ZK6
D2=1.622
D3=.378
D4=.378
D5=1.622
GO TO 3000
QEQQVV=QEQQ/ZNSUM**2
IF((IB01L)120,119,120
120 DPSVV=-DPFVV-2.0*QEQQVV
DPTVV=-DPFVV-QEQQVV
GO TO 102
119 DPSVV=DPFVV-2.0*QEQQVV
DPTVV=DPFVV-QEQQVV
102 XE=XO
XQ=XOUT
IF(XE-XO) 9,16,9

```

```

16 DPFTV=0•0          01626
    QEQQTV=0•0          01627
    DPSTV=0•0          01628
    DPTTV=0•0          01629
    GO TO 17          01630
    IF (XVL-XVG) 19,19,20
18   XO=XVG          01631
19   GO TO 21          01632
20   XO=XVL          01633
21   X1=(XE-XO)/(XIN-XOUT)
    IF (X1) 103,104,103
104  QEQQVT=0•0        01634
    DPSVT=0•0          01635
    DPTVT=0•0          01636
    DPFVT=0•0          01637
    GO TO 105          01638
103  EX=•875          01639
    NX(JQ)=1          01640
    TEMR=ZK2*DT          01641
    DUMP(1)=•533        01642
    DUMP(2)=•174        01643
    DUMP(3)=•0323       01644
    DUMP(4)=•01282       01645
    DUMP(5)=•00666       01646
    DUMP(6)=•0398        01647
    DUMP7=12•5*TEMR      01648
    DUMP8=TEMR*2*((XE-XO)-•5*(XE**2-XO**2)) 01649
    DUMP9=•364*(XE**2.75-XO**2.75)      01650
1=4
    GO TO 2000          01651
22   DPFVT=ZK1/(XIN-XOUT)*DPTPF/ZNSUM**1.75 01652
    D11=ZK2*DTINA        01653
    D10=ZK2*DTOUTA       01654
    D2=1•339          01655
    D3=•378           01656
    D4=•661           01657
    D5=1•622           01658
    GO TO 3000          01659
    QEQQVT=QEQQ/ZNSUM**2 01660
    IF (1B01L) 122,121,122 01661
    DPSVT=-DPFVT-2.0*QEQQVT 01662
    DPTVT=-DPFVT-QEGOVT 01663
    GO TO 105          01664
122

```

```

121 DPSVT=DPSVT-2.0*QE QOVT      01669
DPTVT=DPTVT-QE QOVT      01670
105 IF(XVL-XVG)24,25,26      01671
24 XE=XVG      01672
XQ=XVL      01673
GO TO 27      01674
26 XE=XVL      01675
XO=XVG      01676
GO TO 28      01677
ROUTINE FOR DPTPF.      01678
2000 TEMP=0.0      01679
DO 2001 J=1,6      01680
XJ=FLOATF(J)+EX      01681
TEMP=TEMP+DUMP(J)*(XE**XJ-XO**XJ)
2001 CONTINUE
DPTPF=DUMP9+DUMP7*TEMP-DUMP8
GO TO (7,10,14,22),1
ROUTINE FOR QE-QO
3000 TEMP1=.299*D1***.756
TEMPO=.299*D10***.756
QEQQI=-XE**D2*(TEMPI*(1.0-XE)**D3+XE**D4)/RG
1-((1.0-XE)**D5*(TEMPI*(1.0-XE)**D3+XE**D4)))/(RL*TEMPI)
QEQQO=(XO**D2*(TEMPO*(1.0-XO)**D3+XO**D4))/RG
1+((1.0-XO)**D5*(TEMPO*(1.0-XO)**D3+XO**D4)))/(RL*TEMPO)
QIN(JQ)=-20736.*SAVE2*QEQQI/(DTINA**2*(DTINA**2+DTOUTA**2))*2.0
QOUT(JQ)=-20736.*SAVE2*QEQQO/(DTOUTA**2*(DTINA**2+DTOUTA**2))*2.
QEQQ=QIN(JQ)+QOUT(JQ)
JQ=JQ+1
RAM = 1.E-6
IF(ABSF(QEQQ)-RAM) 87,87,88
67 QEQQ = 0.0
88 GO TO (8,11,15,23),1
4000 GO TO (41,50,64),J
79 IF(ISTA-1)113,113,114
113 DO 127 I=1,4
DO 128 J=1,4
IF(NX(J)-1)128,129,128
128 CONTINUE
127 CONTINUE
129 SUMDQ=QIN(J)/ZNSUM**2
114 IF(ISTA-NST)107,112,107
112 DO 106 K=1,4
I=4-K+1

```

```

DO 108 J=1,4
  IF(NX(J)-1)108,130,108
108  CONTINUE
106  CONTINUE
130  SUMDQ=SUMDQ+QOUT(J)/ZNSUM**2
107  CONTINUE
80   CONTINUE
SUMDPF=SUMDPF*(DT**2*2.0/(DTINA**2+DTOUTA**2))
FRIC = SUMDPF
SUMDPS=SUMDPF-2.0*SUMDQ
40   RETURN
49   FORMAT(32H0 ITERATION FOR CONDENSATION DP.,16H RELATIVE ERROR=E14)
      1.5)
54   FORMAT(50H0 ITERATION FOR CONDENSATION DP FAILED TO CONVERGE./1H1)
63   FORMAT(95H0 THE LOWER BOUND FOR N GIVES A VALUE OF SUM DP WHICH
11S LESS ABSOLUTLY THAN THE INPUT SUM DP. /18H LOWER BOUND OF N=E14
2.5.9H SUM DP=E14.5)
78   FORMAT(23H OUT OF RANGE ON CURVE F5.0,4H KK=I2)
94   FORMAT(7HO XOUT=E20.9,33H IS GREATER THAN OR EQUAL TO XIN=E20.9)
END (1.1.0.1.0)

CALMCON
      SUBROUTINE ALMCON (X1,X2,X3,X4,X5,X6,X7,X8,X9,X10,X11,X12)
      X = X1
      WSUM = X2
      AFUDGE = X3
      ZKL = X4
      DIN = X5
      UG = X6
      UL = X7
      RG = X8
      RL = X9
      CPL = X10
      X11 = HFILM
      X12 = SMW
      TC = 3600.
      PRTL = UL * CPL/ ZKL * TC
      G = 32.17405
      FDP1 = 1.2732395
      PID4 = .785398163397
      PI = .3.141592653589
      IF ((X-1.0) 3.4*4
          2
          4   X = .999
          3   ONEMX = 1.0 - X

```

```

REG = FDPI/DIN * X/UG * WSUM
REL = FDPI/DIN * ONEMX/UL * WSUM
IF(X)30,30,1
IF(REL-2300.)31,31,32
30
31    ZNUS=4.36
      GO TO 33
32    ZNUS = 7.0 + .025*(REL*PRTL)**.8
33    SMW = 0.0
HFILEM = ZNUS*ZKL/DIN
      GO TO 18
1     IF (REG-1000.) 8,10,10
      CX2 = •0049375 * REL**.75 * ONEMX/X * RG/RL * UL/UG
A= 11.0
      GO TO 11
10   CX2=(ONEMX/X)**1.75 * RG/RL * (UL/UG)**.25
A= 19.7
      CX = SQRTF (CX2)
      PHIL2 = 1.0/CX2 + A/CX + 1.0
TAUW = •632 *(WSUM*ONEMX)**2.0*PHIL2/(REL)**.25/G/RL/(PI*PI)
1/ DIN**4.
      TAUSTR = (154.0 * UL/DIN )**2.0/G/RL
      IF(TAUW - TAUSTR) 5,400,400
      IF (REG - 1000.) 7,9,9
5
      CX2 = ONEMX/X * RG/RL * UL/UG
A= 6.0
      GO TO 12
      CX2 = 202.53 * 1.0/REG**.75 * ONEMX/X * RG/RL * UL/UG
A= 12.5
      CX = SQRTF (CX2)
      PHIL2 = 1.0/CX2 + A/CX + 1.0
400   RLML= •299 * CX**.756/(1.0 + •299 * CX**.756)
      HFILEM = 2.0*AFUDGE*ZKL/DIN/(1.0 - SQRTF(1.0 - RLML))
      SMW = SQRTF(1.0 - RLML)
      IF(X - .999)18,17,18
16
17   X = 1.0
      X11 = HFILEM
      X12 = SMW
      RETURN
      END(1,1,0,1,1,1,0,1,0,0,0,0,0,0)
18
CLMCOND SUBROUTINE LMCOND (X1,X2,X3,X4,X5,X6,X7,X8,X9,X10,X11,X12)
      X = X1
      WSUM = X2
      01755
      01756
      01757
      01758
      01759
      01760
      01761
      01762
      01763
      01764
      01765
      01766
      01767
      01768
      01769
      01770
      01771
      01772
      01773
      01774
      01775
      01776
      01777
      01778
      01779
      01780
      01781
      01782
      01783
      01784
      01785
      01786
      01787
      01788
      01789
      01790
      01791
      01792
      01793
      01794
      01795
      01796
      01797

```

```

AFUDGE = X3
ZKL = X4
DIN = X5
UG = X6
UL = X7
RG = X8
RL = X9
CPL= X10
X11 = HFILM
X12 = SMW
TC = 3600.
PRTL = UL * CPL/ ZKL * TC
G = 32.17405
FDPI = 1.2732395
PID4 = 785398163397
P1 = 3.141592653589
1 F (X-1.0) 3.4.4
2 X = 999
3 ONEMX = 1.0 - X
REG = FDPI/DIN * X/UG * WSUM
REL = FDPI/DIN * ONEMX/UL * WSUM
1F (X) 30.30.1
1F (REL-2300.) 31.31.32
2 ZNUS=4.36
3 GO TO 33
ZNUS = 7.0 + .025*(REL*PRTL)**.8
SMW = 0.0
HFILM = ZNUS*ZKL/DIN
31 GO TO 18
1 IF (REG-1000.) 5.6.6
5 IF (REL-1000.) 7.8.8
6 IF (REL-1000.) 9.10.10
CX2 = ONEMX/X * RG/RL * UL/UG
7 GO TO 11
CX2 = .0049375 * REL**.75 * ONEMX/X * RG/RL * UL/UG
8 GO TO 11
CX2 = (ONEMX/X)**1.75 * RG/RL * (UL/UG)**.25
9 CX2 = 202.53 * 1.0/REG**.75 * ONEMX/X * RG/RL * UL/UG
10 CX2 = (ONEMX/X)**1.75 * RG/RL * (UL/UG)**.25
11 CX = SQRTF (CX2)
RLML = .299 * CX**.756/(1.0 + .299 * CX**.756)
HFILM = 2.0*AFUDGE*ZKL/DIN/(1.0 - SQRTF(1.0 - RLML))
SMW = SQRTF(1.0 - RLML)

```



```

01884
01885
01886
01887
01888
01889
01890
01891
01892
01893
01894
01895
01896
01897
01898
01899
01900
01901
01902
01903
01904
01905
01906
01907
01908
01909
01910
01911
01912
01913
01914
01915
01916
01917
01918
01919
01920
01921
01922
01923
01924
01925
01926

400   IF (XX-T(J1)) 301, 306, 400
      DO 302 J=J1, J2
      IF (XX-T(J)) 304, 304, 302
      302  CONTINUE
      309  KK = 2
            XX = T(J2)
            JX1 = J2-N
            GO TO 305
      308  KK = 1
            XX = T(J1)
            JX1 = J1
            GO TO 305
      301  KK = 1
            XX = T(J1)
            JX1 = J1
            GO TO 305
      306  IF (J-J1-1) 301, 306, 307
            IF (J-J2) 303, 308, 309
      304  JX1 = J-N2
      307  CONTINUE
      303  JX1 = J-N2
      305  CONTINUE
      XINT = XX
      IF (NY) 1500, 1500, 3000
      DO 1599 L=1, N1
            X(L) = T(JX1)
            LY = JX1 + NX
            Y(L) = T(LY)
      1599  JX1 = JX1+1
            I = 1
            GO TO 54
      3000  J1 = J1+NX
            J2 = J2+NY
      401  IF (YY-T(J1)) 311, 316, 401
            DO 312 J=J1, J2
            IF (YY-T(J)) 314, 314, 312
            312  CONTINUE
            319  KY = 6
                  YY = T(J2)
            318  JY1 = J2-N
                  GO TO 315
            311  KY = 3
                  YY = T(J1)
            316  JY1 = J1
                  GO TO 315
            314  IF (J-J1-1) 311, 316, 317
            317  IF (J-J2) 313, 318, 319
            313  JY1 = J-N2
            315  CONTINUE

```

```

JX2 = JX1
LY = JY1 + NY*(JX2-11-1)
LY1 = LY
DO 3099 L=1,N1
  X(L) = T(JX2)
  Y(L) = T(LY1)
  LY1 = LY1+NY
3099  JX2 = JX2+1
  I = 0
      GO TO 54
3098  Y(1) = ZZ
      DO 4400 I=1,N
        LY1 = LY+I
        Y(I+1) = 0.
        DO 4050 MM=1,N1
          Y(I+1) = Y(I+1) + T(LY1)*X(MM)
4050  LY1 = LY1+NY
4400  CONTINUE
      DO 4199 L=1,N1
        X(L) = T(JY1)
4199  JY1 = JY1+1
        XINT = YY
        I = 1
54    D = 1.
        X(N+2) = X(1)
        X(N+3) = X(2)
        DO 55 J=1,N1
          A(J+1) = X(J+1) - X(J)
          TPAL1 = XINT - X(J)
          IF (TPAL1) 57,58,57
58    ZZ = Y(J)
        X(1) = 0.
        X(2) = 0.
        X(3) = 0.
        X(4) = 0.
        X(J) = 1.0
        GO TO 59
57    D = D * TPAL1
      GO TO (711,712,713) • N
711  X(J) = TPAL1/A(J+1),
      GO TO 55
712  X(J) = -TPAL1
      GO TO 55

```

```

713 X(J) = (X(J+2)-X(J))*TPAL1
55 CONTINUE
    A(1) = A(N+2)
    ZZ = 0.
    DO 56 J=1,N1
        X(J) = D/(A(J)*A(J+1)* X(J))
        ZZ = ZZ + Y(J)* X(J)
    CONTINUE
56 IF (1) 3098,3098,9999
9999 KK = KK+KY
    RETURN
END (1,0,0,1,0,0)

CBEVAL
SUBROUTINE BEVAL (C,I1,X,Y,Z,K,N)
DIMENSION C(I1)
MARCH 4, 1961

C
NN = 2
K1=11
K13=K1+3
K14=K1+4
K15=K1+5
I=K15
K = 0
XS = X
YS = Y
NDG = C(K1+2)
NSC = C(K1+1)
IF (XS - C(K13)) 2,4,3
IF (XS - C(K14)) 4,4,5
3
2 K = 1
XS = C(K13)
GO TO 4
5 K = 2
XS = C(K14)
IF (NSC - 1) 6,7,6
IF (YS - C(I+1)) 8,98,9
7
6 YS = C(I+1)
K = K+3
GO TO 98
IF (YS - C(I+2)) 98,98,10
9
10 YS = C(I+2)
K = K+6
GO TO 98

```

6 $K1=((NDG+1)*(NDG+2))/2+7$
 K2=K15+K1*(NSC-1)
 J3 = -1
 J1 = 0
 GO TO 11
 = 1+K1
 12 I IF (J1) 13,23,17
 11 IF (XTP - C(I)) 14,99,14
 13 IF (YTP - C(I+1)) 15,15,22
 14 I = -J1
 15 I GO TO 8
 16 I IF (XTP - C(I)) 18,99,18
 17 I = 1-K1
 18 I IF (YTP - C(I+2)) 21,21,20
 19 I = J1
 20 I GO TO 10
 21 I = J1+K1
 22 J1 = 0
 J3 = -1
 23 I IF (J3) 24,29,29
 24 I IF (XS - C(I)) 26,25,99
 25 I IF (XS - C(K14)) 27,26,27
 26 J3 = -2
 XTP = C(I)
 J3 = J3+2
 27 I IF (YS - C(I+1)) 28,98,30
 28 I IF (J3) 8,33,6
 29 I IF (XTP - C(I)) 31,30,31
 30 I IF (YS - C(I+2)) 98,98,99
 31 I IF (J3) 32,34,32
 32 I = 1-K1
 GO TO 10
 33 J1 = -1
 YTP = C(I+1)
 GO TO 99
 34 J1 = 1-K1
 XTP = C(I)
 YTP = C(J1+2)
 99 I IF (1 - K2) 12,35,35
 35 I IF (J1) 14,46,19
 46 I = K2
 GO TO 10
 98 I = 1+6

```

NDG = NDG+1
XN = C(I-3)*XS + C(I-2)
YN = C(I-1)*YS + C(I)
Z = 0.
DO 40 J1 = 1,NDG
XTP = 0.
DO 41 J3 = 1,J1
K1 = I+J3
XTP = XTP*YN + C(K1)
I = I+J1
Z = Z*XN + XTP
IF(K) 42•43•42
IF(N) 44,43,44
40 K1 = C(K1)
WRITE OUTPUT TAPE NN, 45,N,K1,X,Y,X$,$Y,S,Z
FORMAT (5H STEP15,6H CURVE15,7H XINP=E12•5,7H YINP=E12•5,8H XUS
1ED=E12•5,8H YUSED=E12•5,7H ANS=E13•5)
41 RETURN
42 END (1.1.0.1.0)
43 RETURN
44 CSHELLS
      SUBROUTINE SHELLS(RES,PRS,POD,ZNU,CS19RES,KK)
      CALL DEVAL(C19RES,1,RES,POD,ENUMAX,KK,N)
      PSYBAR = 1•C - 1•82/PRS/ENUMAX**1•4
      IF (PSYBAR) 1,1,2
      1 ZNU = 3•65 + 5•75*POD**1•27
      GO TO 3
      2 ZNU = 0•93 + 10•81*POD - 2•01*POD**2 + 0•0252*POD**0•273*(PRS*RES
      1 *PSYBAR)**•3
      3 RETURN
      END
      CCARCOL
      SUBROUTINE CARCOL (X1,X2,X3,X4,X5,X6,X7,X8,X9,X10,X11)
      X=X1
      WSUM = X2
      DTZLC= X3
      UG = X4
      RG = X5
      UL = X6
      RL = X7
      ZKTL = X8
      CPTL = X9
      X10 = H
      X11 = SMW

```

```

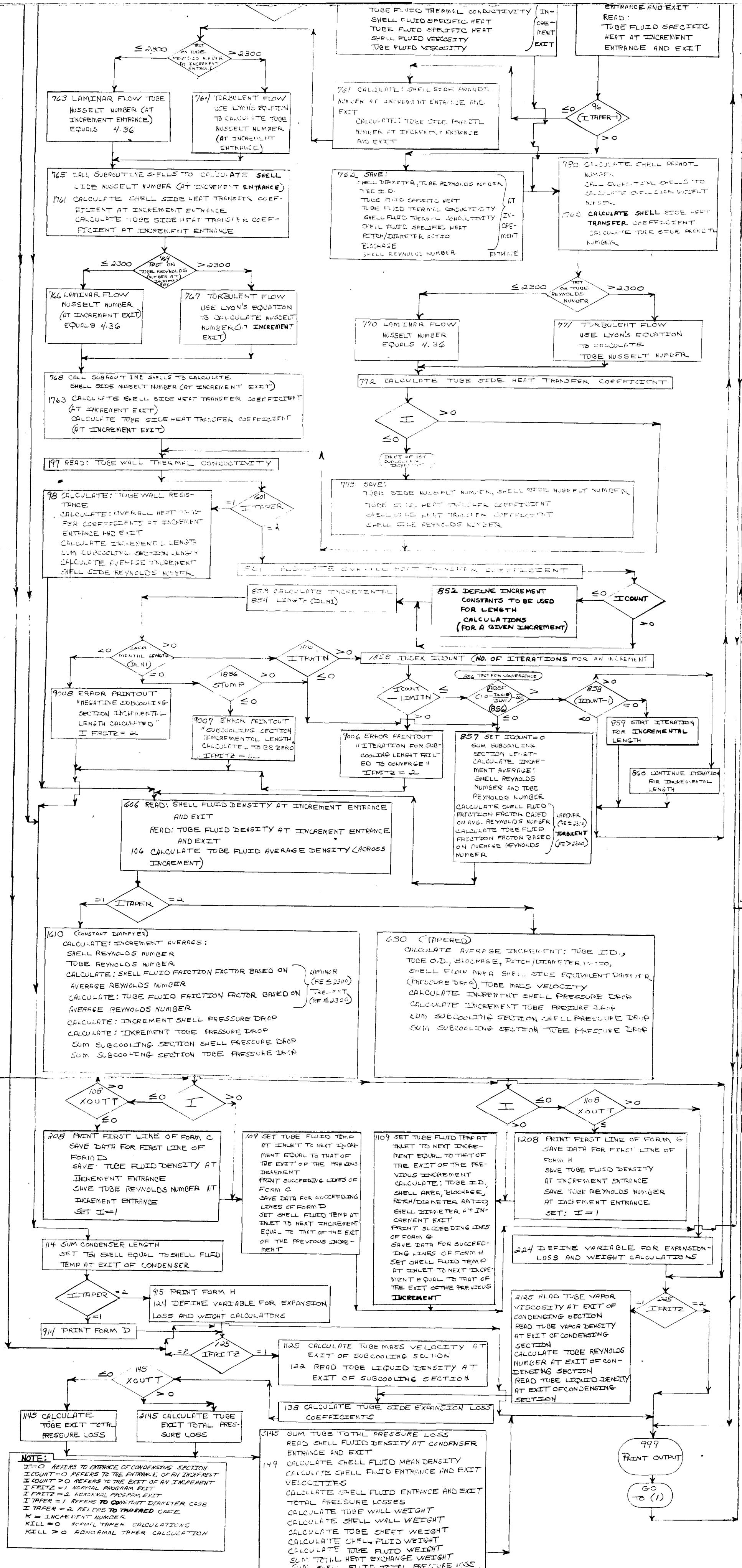
PRTL = UL*CPTL/ZKTL
TC = 3600.
G = 32.17405
FDPI = 1.2732395
PID4 = .785398163397
PI = .5.141592653565
IF (X-1.0) 11.13.13
13 X = .999
ONEMX = 1.0 - X
REG = FDPI/DTZLC * X/UG * WSUM
REL = FDPI/DTZLC * ONEMX/UL * WSUM
GAML = ONEMX/PI * WSUM/DTZLC
IF (X)21.21.22
IF (REL-2300.) 23.23.24
ZNUS = 4.36
GO TO 25
ZNUS = 7.0 + .025 (REL*PRTL)***.3
H = ZNUS*ZKTL*TC/DTZLC
SMW = C.U
GO TO 50
22 IF (REG-1000.) 4.6.6
CX2 = .00493 * REL **.75 * ONEMX/X*RG/RL * UL/UG
4 CX = SQRTF (CX2)
A = 11.0
GO TO 500
6 CX2 = (ONEMX /X) **1.75 * RG/RL * (UL/UG) **.25
CX = SQRTF (CX2)
A = 19.7
500 PHIL2 = 1.0/CX2 + A/CX + 1.0
TAUW = .632*(WSUM*ONEMX)**2.0*PHIL2/(REL)**.25/G/RL/(PI*PI)
1/DTZLC**4.
TAUSTR = (154.0*UL/DTZLC)**2.0/G/RL
IF (TAUW - TAUSTR) 17.18.18
17 IF (REG-1000.) 3.5.5
3 ZX2 = ONEMX /X*RG/RL*UL/UG
ZX = SQRTF (ZX2)
AA = 6.0
GO TO 7
5 ZX2 = 202.8/REG**.75 *ONEMX / X*RG/RL * UL/UG
ZX = SQRTF (ZX2)
AA = 12.5
7 ZPHIL2 = 1.0/ZX2 + AA/ZX + 1.0
SSW = ONEMX *ZPHIL2 * 6.0/G *FDPI /RL * WSUM / DTZLC **3.0 * UL

```

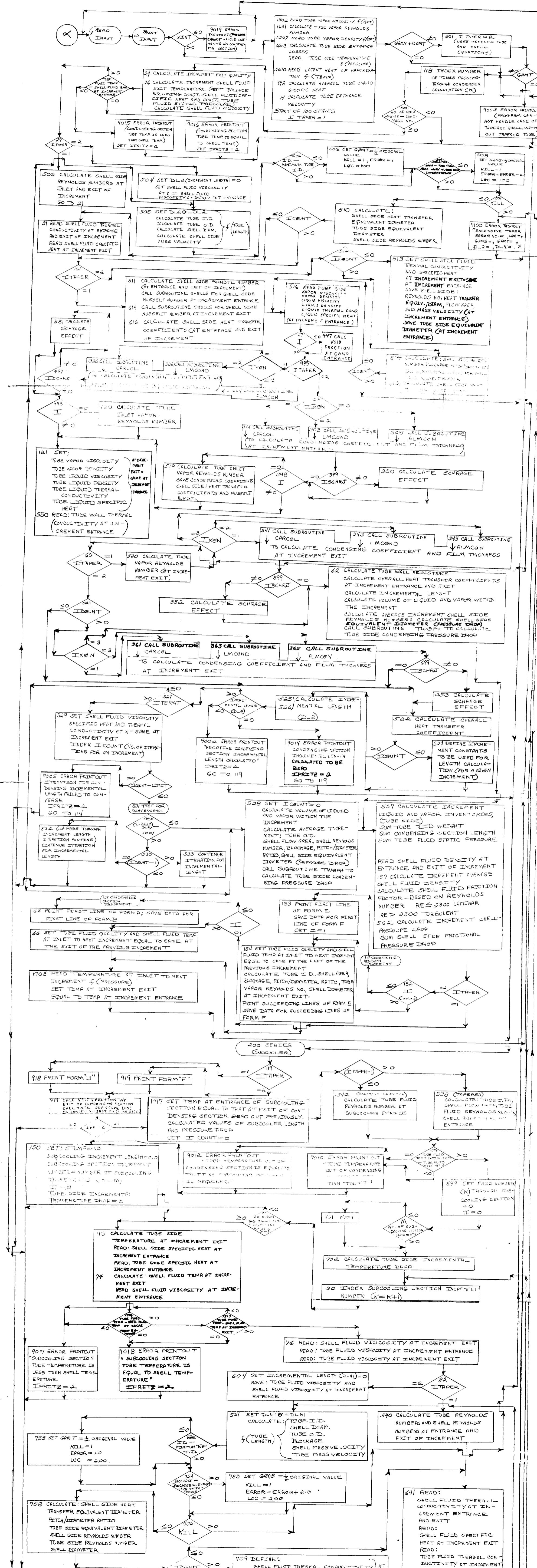

02185	02186	1740.00	1540.00	1140.00	1340.00	0.1893	0.2062	0.2149	0.2173	0.2151	02187	02188
940.00	940.00	1140.00	1340.00	1140.00	1340.00	0.0434	0.0434	0.0463	0.0463	0.0491	0.0517	02189
0.0403	940.00	1140.00	1340.00	1140.00	1340.00	0.00741	0.00741	0.00801	0.00801	0.00849	0.00895	02190
0.00695	940.00	1140.00	1340.00	1140.00	1340.00	44.86	43.31	41.86	40.50	39.23	34.50	02191
940.00	940.00	1140.00	1340.00	1140.00	1340.00	0.445	0.368	0.330	0.301	0.275	0.245	02192
0.445	940.00	1140.00	1340.00	1140.00	1340.00	21.60	20.00	18.43	16.92	15.43	14.00	02193
21.60	850.00	1000.00	1150.00	1150.00	1150.00	1.0037	1.0014	0.9991	0.9968	0.9945	0.9945	02194
850.00	850.00	1000.00	1150.00	1150.00	1150.00	30.27	29.85	29.43	29.00	28.58	28.58	02195
850.00	850.00	1000.00	1150.00	1150.00	1150.00	•830	•768	•707	•647	•608	•608	02196
850.00	850.00	1000.00	1150.00	1150.00	1150.00	27.75	28.30	28.82	29.35	29.98	29.98	02197
940.00	940.00	1140.00	1340.00	1140.00	1340.00	900.00	875.00	846.00	809.00	1450.00	1450.00	02198
900.	950.	1000.	1050.	1000.	1050.	1150.	1200.	1250.	1300.	1350.	1350.	02199
1150.	1150.	1200.	1250.	1250.	1250.	•00111	•00168	•00256	•00371	•01730	•00527	02200
•00111	•00726	•00992	•01320	•01320	•01320	•4153	•6534	1.026	1.026	1.026	0.02228	02201
•4153	3.23	4.52	6.197	6.197	6.197	900.	950.	1000.	1050.	1100.	1100.	02202
900.	1150.	1200.	1250.	1250.	1250.	800.00	1000.00	1000.00	1000.00	1000.00	1000.00	02203
800.00	31.90	32.77	33.62	33.62	33.62	30.96	END OF JOB					02220

APPENDIX 6

Computer Flow Diagrams

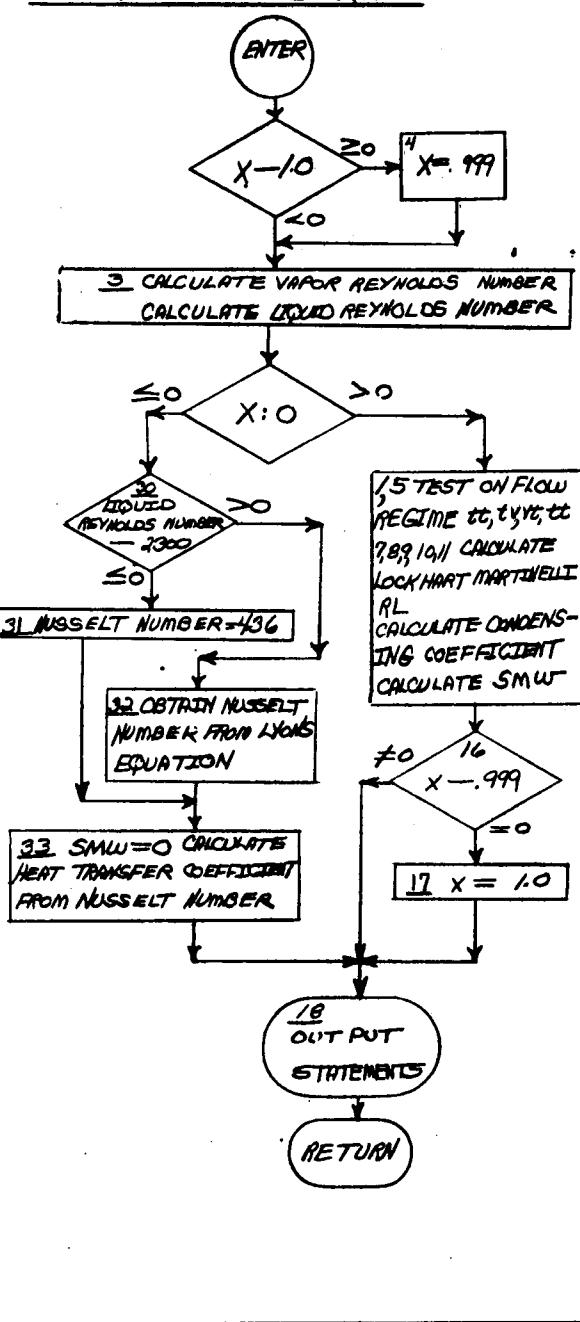


FLOW DIAGRAM FOR MAIN PROGRAM

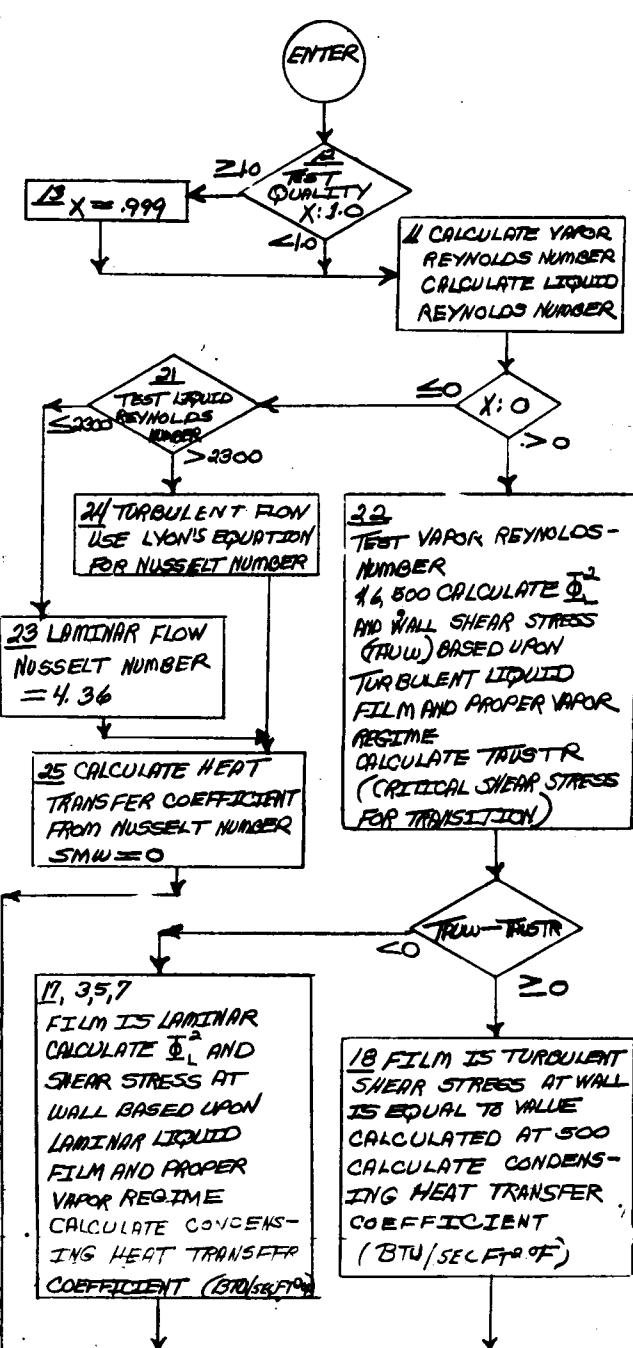


FLOW DIAGRAMS FOR SUBROUTINES

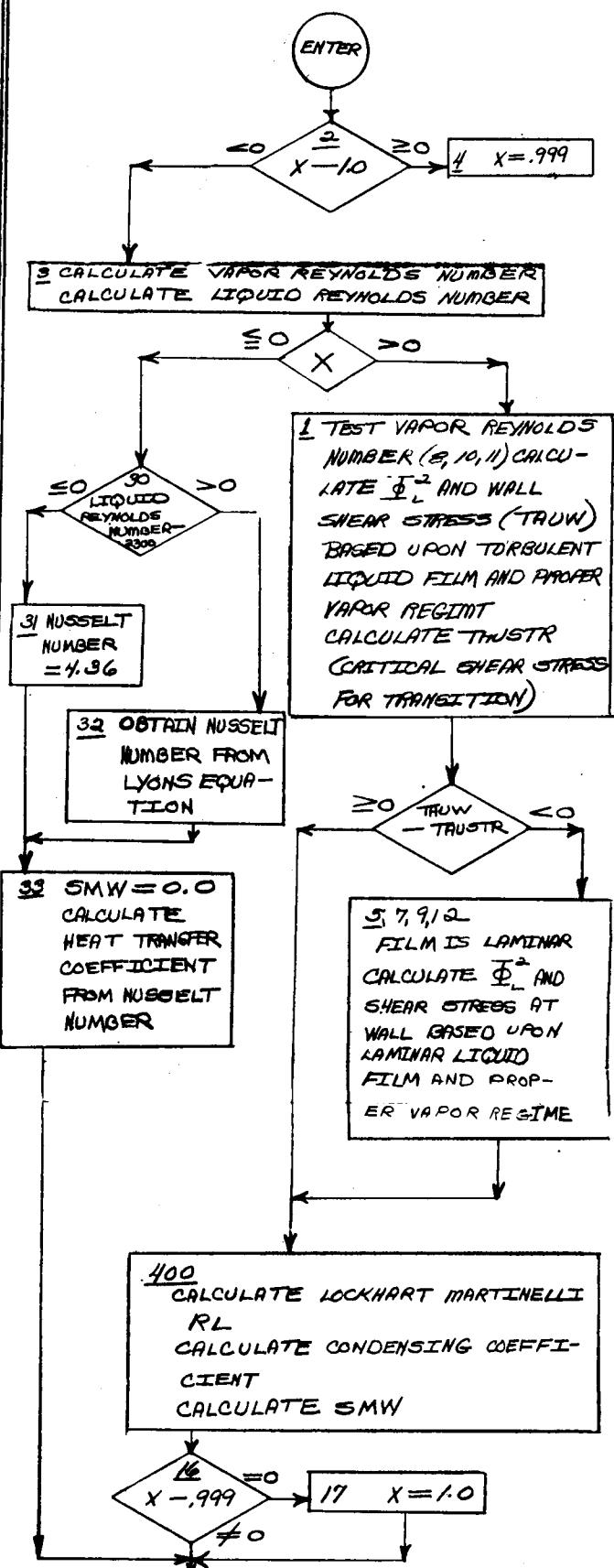
SUBROUTINE LMCON



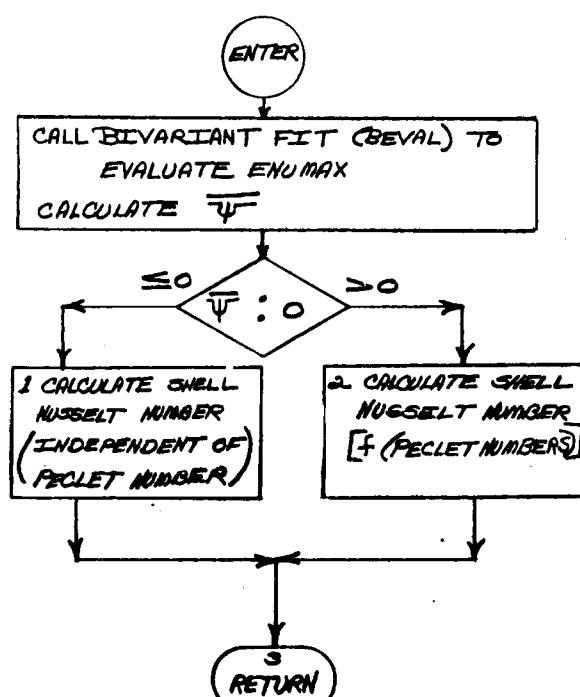
SUBROUTINE CARCOL



SUBROUTINE ALMCON



SUBROUTINE SHELLS



NOTE:

$$SMW = \frac{R_1}{R_2}$$

